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CHAPTER: 1 BIOTECHNOLOGY

1.1 INTRODUCTION

Although the use of Biotechnology has been documented right since very early times in a very rudimentary form, without modifications and innovations, it could be said that modern biotechnology was born in the year 1971 when **Paul Berg's experiments in gene splicing had early success. In 1972** a new technology was advanced by Herbert W. Boyer, University of California, San Francisco (UCSF), in collaboration with Cohen of Stanford University, which involved transferring genetic material into a bacterium, such that the imported material would be reproduced. **Ananda Chakrabarty**, an American-Indian scientist, had **modified a bacteria (of the genus Pseudomonas) capable of breaking down crude oil, which he proposed to use in treating oil spills**. (This work did not involve genetic manipulation; it was rather based on the transfer of entire organelles between strains of the Pseudomonas bacterium). Biotechnology deals with techniques of using **living organisms or enzymes from organisms** to produce products and processes useful to humans.

E.g. : Making curd or bread, are all microbe-mediated processes that could also be thought of as a form of biotechnology.

Growth and maturity of modern biotechnological processes using genetically modified organisms was made possible **only when man learnt to alter the chemistry of DNA and construct recombinant DNA. This key process is called recombinant DNA technology or genetic engineering.**

Note:- **DNA alterations involve using restriction endonucleases, DNA ligase, viral vectors or appropriated plasmids to isolate and transport the foreign DNA into host organisms. It results in expression of the foreign gene, and purification of the gene product. Whereas a Large scale production involves use of bioreactors (Bioreactor is an apparatus in which a biological reaction or process is carried out, especially on an industrial scale).**

Today Biotechnology has a wide range of applications and usage in several fields like Molecular biology, Cell culture, Genetic modification of higher levels in agricultural and scientific development etc.

1.1.1 DEFINITION OF BIOTECHNOLOGY

The wide concept of "biotech" or "biotechnology" covers a range of procedures and techniques for modifications of living (biological) organisms according to human purposes, needs, motives and requirements as per times, and dates back to domesticating animals, cultivating plants, and "**improvements" to these through breeding programs that employ artificial selection and hybridization**. **Modern usage also includes Genetic engineering techniques as well as cell and tissue culture technologies, among many other applications.** Broadly, Biotechnology can be defined as "**use of biological systems of organisms or the use of the living organisms themselves, to make technological advances in order to adapt those technologies to various different fields, ranging from agricultural practice to the medical sector.**

1.1.2 PRINCIPLES OF BIOTECHNOLOGY

The two crucial technologies, which are the core of biotechnological principles are: genetic engineering and chemical engineering.

i. Genetic Engineering

The principle of genetic engineering is to modify the existing organisms by changing the genetic material in them. It mainly includes recombinant DNA technology.

Recombinant DNA Technology is a technique which changes the phenotype of an organism (host) when a genetically altered vector (Genetically modified vectors offer complementary new approaches to integrate with the best existing methods) is introduced and integrated into the genome of the organism. Inserting the desired gene into the genome of the host is not as easy as it sounds. It involves the selection of the desired gene for administration into the host, followed by a selection of the perfect vector with which the gene has to be integrated and recombinant DNA formed. This recombinant DNA then has to be introduced into the host. And at last, it has to be maintained in the host and carried forward to the offspring.

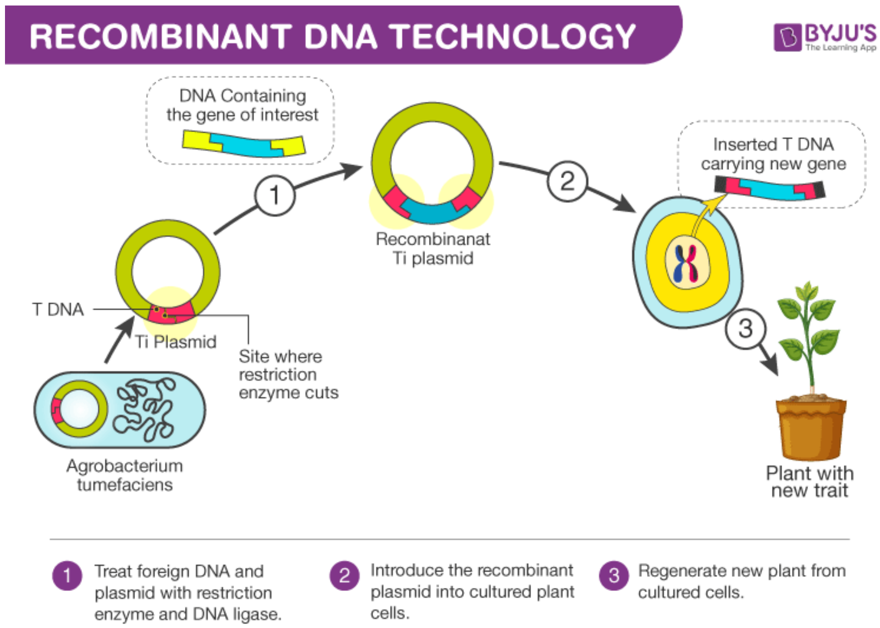


Fig 1.2:Recombinant DNA technology

The genetic engineering or the so-called Recombinant DNA Technology requires certain tools like restriction enzymes, and vectors to carry out the entire process.

ii. Process

- **The restriction enzymes** are a category of nucleases which help make a cut in the DNA at the respective positions.
- The DNA is ligated with the help of ligases before inserting it into the host organism
- The DNA-vector combination is known as the Recombinant DNA which is finally transferred into the host.
- These vectors can independently replicate within the bacterial cells and are, hence, used for the transformation of the recombinant DNA within the host organism.
- This recombinant DNA, also known as the foreign DNA, gets multiplied within the host.
- It is then provided with optimum conditions to induce the expression of the target protein. This protein is known as the recombinant protein.

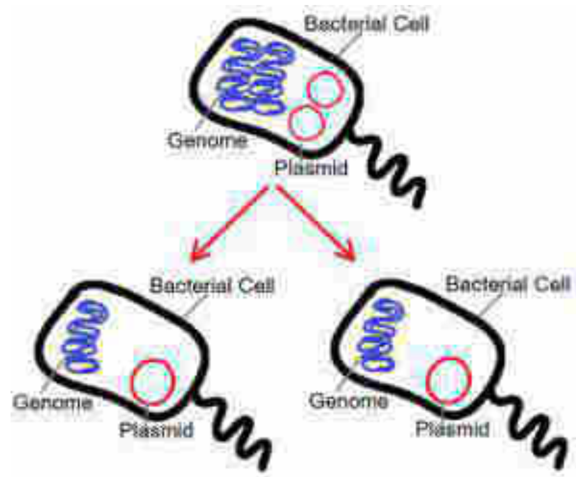


Fig:1.3 Recombinant DNA technology

iii. Three-Parent Baby Technique

Under the three-parent baby technique, human offspring are produced from the genetic material of one man and two women through the use of assisted reproductive technologies specifically mitochondrial manipulation technologies and in-vitro fertilization. In general reproductive technology used to produce three-parent babies focuses on replacing or otherwise reducing the effects of mutations that occur in the DNA of cellular organelles known as mitochondria which are found inside the cytoplasm. The various approaches could help women to overcome infertility and could prevent the transmission to their offspring of potentially debilitating and harmful mitochondrial diseases.

The first three-parent babies were born in the 1990s and early 2000s products of a novel IVF based technique known as a plasmic transfer. The success of the technique was seen as miraculous but its use was controversial it prompted scientist to develop improve technology and cause regulatory agencies to restrict the use of three-parent IVF. Much was unknown about the safety of various three-parent IVF techniques and their use to general human babies raised ethical and social concerns, among them, the primary was the possible impact on health and heredity.

iv. Mitochondrial Manipulation Technologies used in Three parent Baby

Earlier Ooplasmic transfer technology was used for mitochondrial manipulation but due to its side effects, other techniques have evolved, over the years two of which are very significant.

v. Maternal Spindle Transfer

In maternal spindle transfer, the nucleus is removed from a donor egg, leaving behind the cytoplasm. The nucleus from the mother's egg cell is then inserted into the donor egg. The egg is fertilized with the father's sperm and then transferred to the mother's uterus for normal gestation, similar to other IVF procedures.

vi. Transfer

In pronuclear transfer, the mother's egg is first fertilized with the father's sperm, producing a zygote. The pronuclei of the egg and sperm are then removed from the zygote and inserted into a donor egg that has been fertilized and has had its nucleus removed (a pronucleus is the nucleus of the egg or sperm at the stage of fertilization before nuclear fusion). The zygote derived from the donor egg is then implanted into the mother's uterus**.** It is generally seen that as zygote possess a nucleus that houses a genome comprising nuclear DNA from both the father and the mother mitochondria that is how the distinct Junoon which is solely composed of mitochondria DNA from the mother inherited mitochondrial DNA accounts for only a very small percentage of total DNA in the cell get the ability of an egg to be fertilized successfully is thought to be associated with the health of a woman's mitochondria particularly DNA. Operations have been identified as between reduced mitochondria tree and quantity and infertility as well as between mutations and fertilization rates.

Mutations in mitochondrial DNA are a cause of mitochondrial disease which is a heterogeneous group of diseases that can lead to premature death, sometimes in infancy or childhood. Most mitochondrial diseases lack specific treatments, and women who carry the causative mutations are at high risk of transmitting the diseases to their offspring. Risk of transmission is greatest for women with high heteroplasmy women whose total mtDNA content in affected cells or tissues is made up of between 60 and 90 percent mutated mtDNA, the threshold at which mitochondrial disease becomes apparent clinically. However, even women with low heteroplasmy and who are therefore asymptomatic are at risk of passing on mitochondrial disease to their offspring. In such women, heteroplasmy levels can be increased by phenomena such as selective replication of mtDNA and mitochondrial bottleneck, in which only a select number of mtDNA molecules are transferred to eggs at the time of egg maturation.

Hence, both maternal spindle transfer and pronuclear transfer attempt to minimize heteroplasmy by replacing the mother's mitochondria with healthy donor mitochondria. Ooplasmic transfer, on the other hand, may contribute to heteroplasmy, thereby possibly diluting the effects of mutations in maternal mtDNA and enabling embryo survival. The precise mechanisms by which any of the three techniques could potentially treat infertility or prevent inherited mitochondrial disease are not fully known.

1.2 MODERN BIOTECHNOLOGY

Biotechnology, through genetic engineering, works directly with the genetic material of a cell. If we examined a cell under a high-powered microscope, we would see long, thread-like structures called chromosomes. These chromosomes, composed of DNA (deoxyribonucleic acid), are organized into sections called genes. Genes control the production of particular proteins, and proteins, in turn, determine the characteristics of an organism. In some cases, a gene may govern one particular trait, such as an organism's resistance to disease, while in other cases, characteristics may be determined by many genes. It was the understanding of DNA that paved the way for genetic engineering. The knowledge gained has allowed researchers to transfer genes between the cells of different organisms.

Cut and paste method

In this method, the actual transfer of a gene is carried out in a complex "cut and paste" procedure. In the cut and paste method, Specialized enzymes are used to "cut" or remove a specific gene from one organism's DNA, and then to "paste" or slice that gene back into the DNA of another organism.

The gene can be inserted into another organism through a variety of techniques, depending upon the characteristics and properties of the recipient organism, or whether the organism is an animal, bacterium or a plant. Some of the genetic engineering techniques used to modify organisms are:

ANIMALS	PLANTS	BACTERIA
A technique called **micro-injection** is the method often used to produce genetically engineered or transgenic animals. Through this technique, a very fine needle is used to inject a solution of DNA molecules containing genes that carry desired characteristics (such as disease resistance) into animal cells, usually at the embryo stage. The genes are incorporated into the animal cells genetic material, and the cells begin to express the characteristic determined by the new gene. Applying this micro-injection technique could have potential benefits for agriculture as well.	Plant cells have tough outer walls, making the delivery of genes into the plant cells a little more challenging than is the case for bacteria. There are two main techniques by which this process is carried out. The first of these involves the use of a modified species of a bacterium called Agrobacterium. In nature, the Agrobacterium invades a plant, then infects it with a segment of its own DNA that "codes" for the development of crown gall disease. This DNA is incorporated into the plant's DNA, and the plant becomes diseased with crown gall. When using Agrobacterium to modify plants genetically, these disease-causing parts of the Agrobacterium's DNA are removed. They are replaced with genes that carry desired characteristics (such as improved nutritional value) by the "cut and paste" procedure. The Agrobacterium can then be introduced to plant cell material,	In certain bacteria, small naturally occurring circular segments of DNA called plasmids are found, which can be used for genetic engineering. Plasmid DNA can be taken outside of the bacterial cell, modified with the addition of a new gene, and placed back into the cell. With the new gene, the bacterial cell can now manufacture the product of this gene as its own. Because bacteria reproduce very rapidly, large volumes of bacteria containing the modified plasmid can be used to produce commercially significant quantities of a gene product, such as a food additive or an animal vaccine, in short periods of time.

	where it is allowed to invade plant cells and introduce the new gene with the desired characteristics. The full plants grown from these plant cells express the characteristic determined by the new gene. Agrobacterium, therefore, is a convenient delivery system by which new characteristics can be passed on to plants.	

Particle Gun Method

The second technique used to deliver genetically engineered DNA into plants is called the DNA "particle gun" method. Tiny metal particles coated with genes with desired characteristics, such as improved nutritional value, are put into a particle gun and fired directly into plant cells. These genes are incorporated into the plant cell's DNA, and the cells are then grown into full plants. The new characteristic is thereafter present in the whole plant.

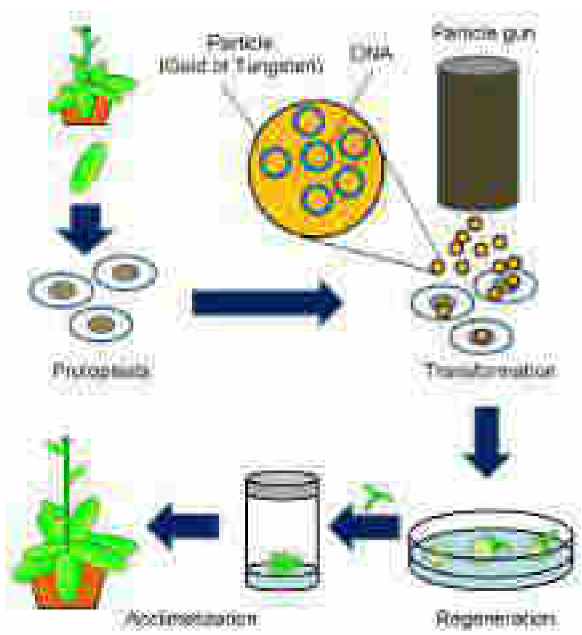


Fig 1.4: Particle gun Method

Plasmid Method

This method is the most commonly used in genetic engineering. This method uses small circular pieces of a DNA molecule called plasmids. This method is mainly used for altering microorganisms such as bacteria.

1) The plasmid is inserted into a container containing restriction enzymes. Restriction enzymes cut up the plasmids into small pieces.

2) Using the restriction enzymes, these cut pieces of plasmids are inserted into the bacteria and due to which sticky ends are produced. A sticky end refers to how the restriction enzyme cuts the DNA. If the cut was straight, then it is a blunt end, but if it is a staircase then it's sticky.

3) The sticky ends on the DNA from the plasmids combine with the sticky ends on the DNA inside the bacteria to form a ring of DNA. Other enzymes are added to make those ringed DNA molecules more stable. After they stabilize, they are put in safety to use for further processes.

4) A culture of live bacteria is then prepared with the newly formed plasmids and are placed together. These plasmids will then enter into the bacterial cell, and start expressing itself. During the expression, the plasmid will synthesize new proteins or antibiotic resistance genes. These new genes will help distinguish the plasmid bacteria from the non-plasmid bacteria.

Vector Method

A vector in molecular biology means a molecule of DNA, which serves as a carrier of genetic information into the cells. It is used especially in molecular genetics. Generally, it is consisting of inserted DNA sequence and larger DNA sequence which serves as a supporting structure. The most common vectors are plasmids, viruses, and artificial chromosomes.

Vectors are used especially to transfer genetic information into the cells to replicate and express the selected part of DNA. The whole process is induced by a promoter which is also contained in vector DNA. Inserting vectors into cells is called due to the target cell: transformation (for bacterial cells), transfection (for eukaryote), transduction (for viruses).

The vector method uses techniques similar to the plasmid method. This method uses vectors, which are small carrier molecules, which are normally viruses. Viruses are made of a protein capsule and have their DNA inside, and they attach onto a cell then inserts its DNA or RNA into the host cell, then it detaches itself. The DNA, now inside the host cell, will start replicating itself by using the genetic information of the host cell, which means the gene that was inserted will now be part of the host cell. The vector method is better than the plasmid method because the plasmid method offers genetic variation. After all, the newly formed plasmids are made with random pieces of DNA, while the vector method uses a specific gene to get a specific result. This will make the host give the desired features.

1) The strand of DNA is put into a container with specific restriction enzymes to separate a specific gene. Once the restriction enzyme cuts the gene of interest, that gene is then isolated from the rest and is ready to be inserted into a vector.

2) This gene is now inserted into a vector, in this case, it's a virus, and once the virus has accepted the gene of interest, it becomes a recombinant molecule. A recombinant molecule is just a vector with recombinant DNA attached.

3) The vector is now placed with the host cell, where it transfers the DNA to the cell. Once inside the cell, the DNA starts to replicate, the scientist then stops the vector's DNA from replicating and only allows the gene of interest to replicate.

4) The gene is now inside the host cells' DNA, and now the cell will have this gene.

Gel Electrophoresis

It is a technique that is used to directly see DNA fragments. Like, researchers can analyze the results of a PCR reaction by examination of the DNA fragments it produces on a gel. Gel electrophoresis leads to the separation of DNA fragments based on their size, and the fragments are stained with a dye so that researchers can see them.

1.3 APPLICATIONS OF BIOTECHNOLOGY

Biotechnology is an emerging field of research as it has the potential to solve many biological problems which have not been solved until now with the conventional techniques. Biotechnology extends its applications over a broad spectrum which includes medicines, agriculture, transgenics, genetic engineering, etc. Here we will discuss biotechnology in agriculture.

Fig:1.5 Applications of Biotechnology

1.3.1 TYPES OF BIOTECHNOLOGY

RED(MEDICINAL) BIOTECHNOLOGY	Medical biotechnology is the use of living cells and other cell materials for the purpose of bettering the health of humans. **E.g.:- Vaccine**
GREEN(AGRICULTURAL) BIOTECHNOLOGY	Agricultural biotechnology focuses on developing genetically modified plants for the purpose of increasing crop yields or introducing characteristics to those plants that provide them with an advantage. **E.g.:- Selective plant and animal breeding**
WHITE (INDUSTRIAL) BIOTECHNOLOGY	Creation of new and innovative materials, cellular structures etc

BLUE (ENVIRONMENTAL) BIOTECHNOLOGY(Marine, Aquatic, Plant and Animal etc)	Use of natural resources or biological modification techniques for lessening the impacts on environment **E.g:- biofuels, Ocean or marine engineering**
GOLD(NANO-BIOTECHNOLOGY)	It is the intersection of Nanotechnology and biotechnology, and this discipline helps to indicate the merger of biological research with various fields of nanotechnology
GREY (FORENSIC) BIOTECHNOLOGY	Forensic analysis of biological evidence using biotechnology methods is increasingly important in criminal investigations**.** **E.g.:- Analysis of proteins in the blood (serology), other body fluids and body tissues are some of the tradi-tional methods in forensic analysis.**

1.3.1 AGRICULTURE AND BIOTECHNOLOGY

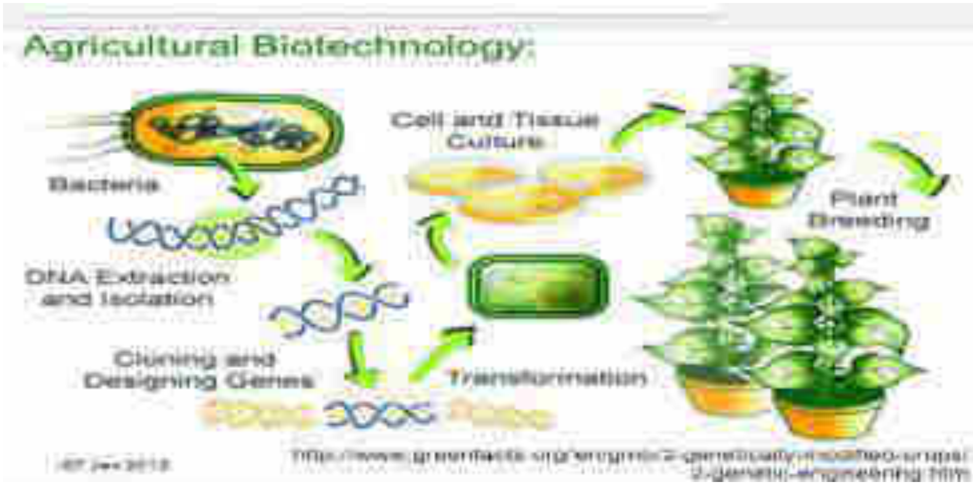
The large increase in the size of a population has led to a greater demand for basic requirements, including food, shelter, clothing, etc. Another impact of population on crops production is the exploitation of the land. Thus cultivation has been limited to a small area. In order to meet the demands with limited resources, we need to apply a great effort. Biotechnology in agriculture has changed the face of this condition. It is widely employed in different fields, and agriculture is one among them. Researchers have suggested different options for increasing food production. Genetically engineered crop-based agriculture is an option, others being agrochemical based agriculture and organic agriculture. **The Green revolution** was an initiation for increasing food production, but it couldn't meet the growing demands. Later an idea was put forward for improvement of crop variety. There was also increasing use of agrochemicals. However, the increasing use of chemicals for these improved crop varieties seemed to be unfeasible for farmers. In addition, the environmental issues related to them also reduced their use.

i. Genetically Modified Crops (GMO):

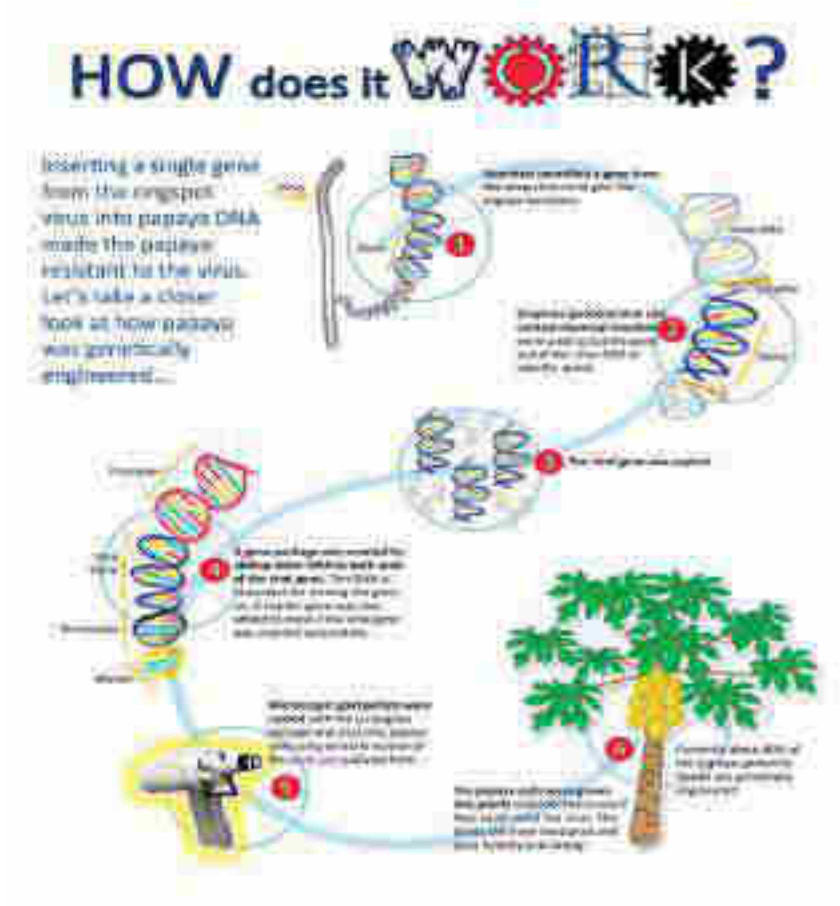
Genetically modified crops (GMO) a result of the alteration in the genetic makeup of the crops, are the latest advancement in the agricultural field.This modification leads to a number of advantages in the crops which include:-

One of the most common examples is that of Bt Cotton. Bt stands for Bacillus thuringiensis which, when introduced in plants develop resistance against pests like bollworms and corn borer. Thus, genetically modified crops help in optimizing the complete process of agriculture. Advancement of biotechnology in agriculture resulted in a variety of GMO, which include pest-resistant plants, disease-resistant plants, etc.

ii. Some examples of Agriculture Biotechnology



<u>Fig:1.6 Agriculture Biotechnology</u>



<u>Fig:1.7 Biotechnology in Papaya plant</u>

(Image source: Nature.com)

1.4 APPLICATIONS OF BIOTECHNOLOGY IN MEDICINE

The process of recombinant DNA technology has made an immense impact in the area of healthcare by enabling mass production of safe and more effective therapeutic drugs. Also, this technology does not induce unwanted immunological responses which are very common in similar products isolated from non-human sources.

Note:- Currently, about 30 recombinant therapeutics have been approved for the use of humans all over the world. Moreover, in India, 12 of these are presently being marketed.

i. Insulin

- Insulin is required by diabetic patients to remove excess sugar from the blood. Diabetic patients have a very low level of insulin or no insulin produced by the body. Therefore they need external insulin to control the blood glucose levels.
- Later it was discovered that the insulin produced by the pancreas of the pigs could be used by humans. But there were not enough pigs to provide the quantities of insulin required. This led to the cloning of the human insulin gene.
- The specific gene sequence that codes for human insulin were introduced in E.coli bacteria.
- The gene sequence altered the genetic composition of the E.coli cells. Within 24 hours, several E.coli bacteria containing the recombinant human insulin gene were produced. The recombinant human insulin was isolated from E.coli cells.

ii. Gene Therapy

Gene Therapy holds the most promising answer to the problem of genetic diseases. Gene therapy is used to treat genetic disorders usually by the insertion of a normal gene or correct gene for the defective or inactive gene into an individual with the help of vectors such as retrovirus, adenovirus, and herpes simplex virus. The normal gene replaces the defective or inactive gene and carries out its functions. The therapy has the highest chances of developing a permanent cure if introduced in the earliest stages of life.

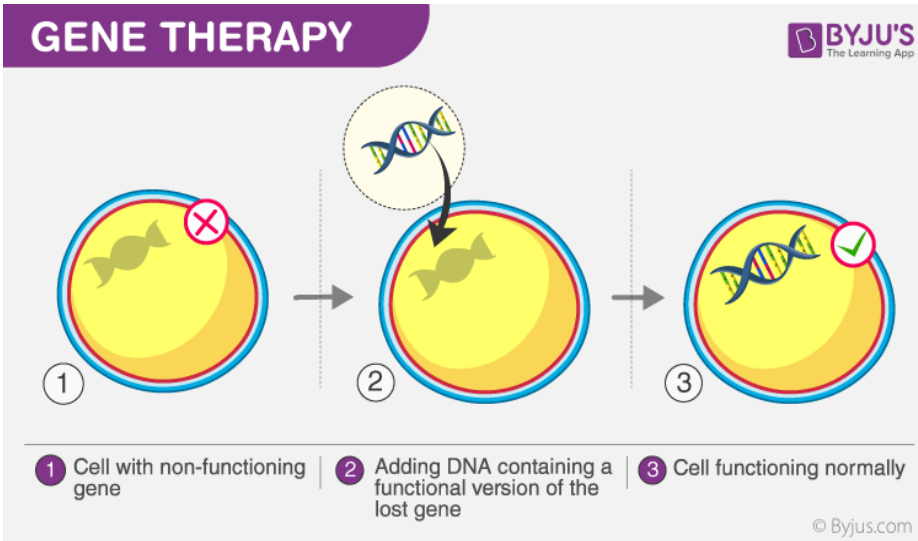
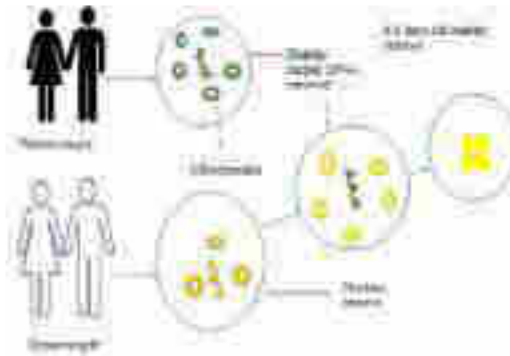


Fig:1.8 Gene Therapy

In the above figure, the cell with the defective gene is injected with a normal gene which helps in the normal functioning of the cell. This technique is employed mainly to fight against the diseases in the human body and also to treat the genetic disorders. The damaged proteins are replaced in the cell by the insertion of DNA into that cell. Generally, the improper protein production in the cell leads to diseases. These diseases are treated using gene therapy techniques. For example, cancer cells contain faulty cells which are different from the normal cells and have defective proteins. Hence, if these proteins are not replaced, this disease would prove to be fatal.

iii. Types of Gene Therapy

Somatic Therapy	Germline Therapy
This type usually occurs in the somatic cells of the human body. This is related to a single person and the only person who has the damaged cells will be replaced with healthy cells.In this method, therapeutic genes are transferred into the somatic cells or the stem cells of the human body. This technique is	It occurs in the germline cells of the human body. Generally, this method is adopted to treat the genetic, disease causing-variations of genes which are passed from from the parents to their children. The process involves introducing a healthy DNA into the cells responsible for producing reproductive cells,

considered as the best and safest method of gene therapy. 	eggs or sperms. Germline gene therapy is not legal in many places as the risks outweigh the rewards. 

Somatic Cells	A somatic cell is any cell of the body except sperm and egg cells. Somatic cells are diploid, meaning that they contain two sets of chromosomes, one inherited from each parent. Mutations in somatic cells can affect the individual, but they are not passed onto offspring.
Germline Cells	Germ cells are cells that create reproductive cells called gametes. Germ cells are also diploid, but they are found only in the gonads. Gonads are the ovaries in females and testes in males. In these organs, females make gametes called eggs, and males make gametes called sperm. Gametes are haploid cells, which means that they have only one set of chromosomes. In humans, gametes have 23 chromosomes.

iv. Applications of Gene Therapy

- It is used in the replacement of genes that cause medical ill-health
- The method generally destroys the problem causing genes
- It helps the body to fight against diseases by adding genes to the human body
- This method is employed to treat diseases such as cancer, ADA deficiency, cystic fibrosis, etc.

v. *Molecular Diagnosis*

Medical diagnosis is another application of biotechnology in the health sector. Many times the pathogen concentration increases by the time the disease is diagnosed. Hence, early diagnosis and knowledge of pathophysiology are essential for an effective cure. This can be achieved with the help of techniques such as Recombinant DNA Technology, Polymerase Chain Reaction (PCR) and Enzyme-Linked Immunosorbent Assay (ELISA), etc.

vi. *Pharmacogenomics*

Pharmacogenomics has led to the production of drugs that are best suited to an individual's genetic makeup. It can be applied to diseases such as cancer, depression, HIV, asthma, etc.

vii. *Edible Vaccines*

Vaccines are obtained by animals and cell cultures. These vaccines contain inactivated pathogens. The transgenic plants can produce antigens that can be used as edible vaccines. Antigenic proteins from several pathogens can be expressed in plants such as tomato and banana. Transgenic sugar beet can treat foot and mouth disease of animals, transgenic bananas and tomatoes can cure diseases such as cholera and hepatitis B.

viii. *Transgenic Animal*

Transgenic animals are animals with modified genomes. A foreign gene is inserted into the genome of the animal to alter its DNA. This method is done to improve the genetic traits of the target animal. Initially, the improvement of genetic traits was done by selective breeding methods. In this, the animals with desired genetic characteristics were mated to produce an individual with improved genetic characteristics. Since this technique was time-consuming and expensive, it was later replaced by recombinant DNA technology. Transgenesis is the phenomenon in which a foreign gene with desired characteristics is introduced into the genome of the target animal. The foreign gene that is introduced is known as the transgene, and the animal whose genome is altered is known as transgenic. These genes are passed on to successive generations. The transgenic animals are genetically engineered and are also known as genetically modified organisms. The first genetically modified organism was engineered in the year 1980.

1.4.1 Methods for Creating Transgenic Animals

i. *Physical Transfection*

In this method, the gene of interest is directly injected into the pronucleus of a fertilized ovum. It is the very first method that proved to be effective in mammals. This method applied to a wide variety of species. Other methods of physical transfection include particle bombardment, ultrasound, and electroporation.

ii. *Chemical Transfection*

One of the chemical methods of gene transfection includes transformation. In this method, the target DNA is taken up in the presence of calcium phosphate. The DNA and calcium phosphate co-precipitates, which facilitates DNA uptake. The mammalian cells possess the ability to take up foreign DNA from the culture medium.

iii. *Retrovirus-Mediated Gene Transfer*

To increase the chances of expression, the gene is transferred utilizing a vector. Since retroviruses can infect the host cell, they are used as vectors to transfect the gene of interest into the target genome.

iv. *Viral Vectors*

Viruses are used to transfect DNA into the animal cell. The viruses possess the ability to infect the host cell, express well, and replicate efficiently.

v. *Bactofection*

It is the process by which the gene of interest is transferred into the target gene with the help of bacteria

vi. *Examples of Transgenic Animals*

Following are the examples of transgenic animals from India

- **Dolly Sheep:** Dolly the sheep was the first mammal to be cloned from an adult cell. In this, the udder cells from a 6-year-old Finn Dorset white sheep were injected into an unfertilized egg from a Scottish Blackface ewe, which had its nucleus removed. The cell was made to fuse by electrical pulses. After the fusion of the nucleus of the cell with the egg, the resultant embryo was cultured for six to seven days. It was then implanted into another Scottish Blackface ewe which gave birth to the transgenic sheep, Dolly.

- **Transgenic Mice:** Transgenic mice are formed by injecting DNA into the oocytes or one or two-celled embryos obtained from female mice after hormonal treatment. After injecting the DNA, the embryo is implanted into the uterus of receptive females. It is developed by the National Institute of Immunology and International Centre For Genetic engineering and Biotechnology

vii. Applications of Transgenic Animals

The transgenic animals are created because of the benefits they provide to the man. Let us discuss a few of them here.

viii. Normal Physiology and Development

In transgenic animals, a foreign gene is introduced due to which the growth factor is altered. Hence, these animals facilitate the study of gene regulation and their effect on the everyday functions of the body.

1.4.2 Study of Diseases

Transgenic animals are specially designed to study the role of genes in the development of certain diseases. Moreover, to devise a cure for these diseases, the transgenic animals are used as model organisms. These transgenic models are used in research for the development of medicines. For example, we have transgenic models for diseases such as Alzheimer's and cancer.

i. Biological Products

Several biological products, such as medicines and nutritional supplements, are obtained from transgenic animals. Research for the manufacture of medicines to treat diseases such as phenylketonuria (PKU) and hereditary emphysema is going on. The first transgenic cow, Rosie, in 1997, produced milk that was rich in human protein (2.4 grams per liter). This milk contains the human gene alpha-lactalbumin and could be given to babies as an alternative to natural cow milk.

ii. Vaccine Safety

- Transgenic animals are used as model organisms for testing the safety of vaccines before they are injected into humans. This was conventionally done on monkeys.

ELISA Technique

ELISA is a basic enzyme-linked immunosorbent assay (also shortened as EIA: Enzyme Immunoassay) that is carried out to detect and measure antibodies in the blood. Antibodies are blood proteins produced in response to a specific antigen. It helps to examine the presence of antibodies in certain infectious disorders.

ELISA is a distinguished analysis compared to other antibody-assays as it yields quantitative results and separation of non-specific and specific interactions that take place through serial binding to solid surfaces, which is normally a polystyrene multiwell plate.

iii. Polymerase Chain Reaction (PCR)

Polymerase chain reaction (PCR). The polymerase chain reaction is another widely used DNA manipulation technique, one with applications in almost every area of modern biology. PCR reactions produce many copies of a target DNA sequence starting from a piece of template DNA. This technique can be used to make many copies of DNA that are present in trace amounts (e.g., in a droplet of blood at a crime scene).

1.4.3 INDUSTRIAL BIOTECHNOLOGY

Industrial biotechnology is one of the most promising new approaches to pollution prevention, resource conservation, and cost reduction. It is often referred to as the third wave in biotechnology. If developed to its full potential, industrial biotechnology may have a larger impact on the world than health care and agricultural biotechnology. It offers businesses a way to reduce costs and create new markets while protecting the environment. Also, since many of its products do not require the lengthy review times that drug products must undergo, it's a quicker, easier pathway to the market. Today, new industrial processes can be taken from lab study to commercial application in two to five years, compared to up to a decade for drugs.

The application of biotechnology to industrial processes is not only transforming how we manufacture products but is also providing us with new products that could not even be imagined a few years ago. Because industrial biotechnology is so new, its benefits are still not well known or understood by the industry, policymakers, or consumers.

From the beginning, industrial biotechnology has integrated product improvements with pollution prevention. Nothing illustrates this better than the way industrial biotechnology solved the phosphate water pollution problems in the 1970s caused by the use of phosphates in laundry detergent. Biotechnology companies developed enzymes that remove stains from clothing better than phosphates, thus enabling replacement of a polluting material with a non-polluting biobased additive while improving the performance of the end product. This innovation dramatically reduced phosphate-related algal blooms in surface waters around the globe and simultaneously enabled consumers to get their clothes cleaner with lower wash water temperatures and concomitant energy savings.

Rudimentary industrial biotechnology dates back to at least 6000 B.C. when Neolithic cultures fermented grapes to make wine, and Babylonians used microbial yeasts to make beer. Over time, humanity's knowledge of fermentation increased, enabling the production of cheese, yogurt, vinegar, and other food products. In the 1800s, Louis Pasteur proved that fermentation was the result of microbial activity. Then in 1928, Sir Alexander Fleming extracted penicillin from mold. In the 1940s, large-scale fermentation techniques were developed to make industrial quantities of this wonder drug. Not until after World War II, however, did the biotechnology revolution begin, giving rise to modern industrial biotechnology.

Since that time, industrial biotechnology has produced enzymes for use in our daily lives and the manufacturing sector. For instance, a meat tenderizer is an enzyme, and some contact lens cleaning fluids contain enzymes to remove sticky protein deposits. In the main, industrial biotechnology involves the microbial production of enzymes, which are specialized proteins. These enzymes have evolved in nature to be super-performing biocatalysts that facilitate and speed-up complex biochemical reactions. These amazing enzyme catalysts are what make industrial biotechnology such a powerful new technology.

Industrial biotechnology involves working with nature to maximize and optimize existing biochemical pathways that can be used in manufacturing. The industrial biotechnology revolution rides on a series of related developments in three fields of study of detailed information derived from the cell: genomics, proteomics, and bioinformatics. As a result, scientists can apply new techniques to a large number of microorganisms ranging from bacteria, yeasts, and fungi to marine diatoms and protozoa.

Industrial biotechnology companies use many specialized techniques to find and improve nature's enzymes. Information from genomic studies on microorganisms is helping researchers capitalize on the wealth of genetic diversity in microbial populations. Researchers first search for enzyme-producing microorganisms in the natural environment and then use DNA probes to search at the molecular level for genes that produce enzymes with specific biocatalytic capabilities. Once isolated, such enzymes can be identified and characterized for their ability to function in specific industrial processes. If necessary, they can be improved with biotechnology techniques.

Many biocatalytic tools are rapidly becoming available for industrial applications because of the recent and dramatic advances in biotechnology techniques. In many cases, the biocatalysts or whole-cell processes are so new that many chemical engineers and product development specialists in the private sector are not yet aware that they are available for deployment. This is a good example of a "technology gap" where there is a lag between availability and widespread use of new technology. This gap must be overcome to accelerate progress in developing more economical and sustainable manufacturing processes through the integration of biotechnology. "New Biotech Tools for a Cleaner Environment" provides dramatic illustrations of what these powerful new tools can do. The report aims to spark more interest in this powerful technology, to help close this technology gap, and facilitate progress toward a more sustainable future.

Fig:1.9 Industrial Biotechnology

(Image Source:nuclineers.com)

1.4.4 ENVIRONMENTAL BIOTECHNOLOGY

Environmental biotechnology is biotechnology that is applied to and used to study the natural environment. Environmental biotechnology could also imply that one tries to harness biological processes for commercial uses and exploitation.

The International Society for Environmental Biotechnology defines environmental biotechnology as "**the development, use and regulation of biological systems for remediation of contaminated environments (land, air, water), and environment-friendly processes (green manufacturing technologies and sustainable development).**

Significance of Environmental Biotechnology in Sustainable Development and climate change mitigation

There have been increasing calls for the advancement of small-scale agro-ecological farming systems and technology in order to achieve food security, climate change mitigation, climate change adaptation and the realization of the Millennium Development Goals. Environmental biotechnology has been shown to play a significant role in **agroecology** in the form of zero waste agriculture and most significantly through the operation of over 15 million biogas digesters worldwide.

1.4.5 BIOREMEDIATION

Bioremediation is a biotechnical process, which abates or cleans up contamination. It is a type of waste management technique which involves the use of organisms to remove or utilize the pollutants from a polluted area.

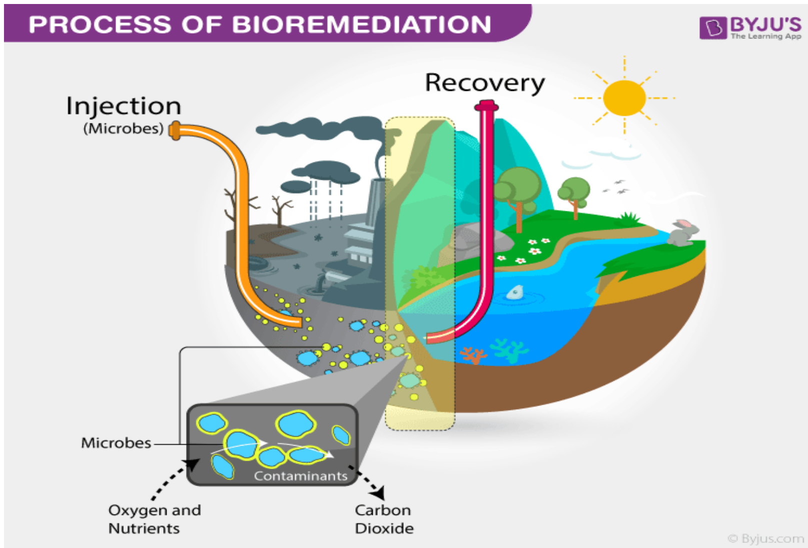


Fig: 1.10 Bioremediation technique

There are several remedies where contaminated water or solid is purified by chemical treatment, incineration, and burial in a landfill. There are other types of waste management technique which include solid waste management, nuclear waste management, etc. Bioremediation is different as it uses no toxic chemicals. Microorganisms like Bacteria and Fungi are the main role players when it comes to executing the process of Bioremediation. Bacteria are the most crucial microbes in this process as they break down the waste into nutrients and organic matter. Even though this is an efficient process of waste management, bioremediation cannot destroy 100% contaminants. Bacteria can easily digest contaminants like chlorinated pesticides or clean oil spills but microorganisms fail to destroy heavy metals like lead and cadmium.

1.4.6 Types of Bioremediation

IN-SITU	EX - SITU
Bioventing: supply of air and nutrients through wells to contaminated soil to stimulate the growth of indigenous bacteria. It is used for simple hydrocarbons and can be used where the contamination is deep under the surface.	**Land farming**: contaminated soil is excavated and spread over a prepared bed and periodically tilled until pollutants are degraded. The goal is to stimulate indigenous biodegradative microorganisms and facilitate their aerobic degradation of contaminants.
Biosparging: Injection of air under pressure below the water table to increase groundwater	**Biopiles**: it is a hybrid of land farming and composting. Essentially, engineered cells are

oxygen concentrations and enhance the rate of biological degradation of contaminants by naturally occurring bacteria	constructed as aerated compost piles. Typically used for treatment of surface contamination with petroleum hydrocarbons
Bioaugmentation - At times, there are certain sites where microorganisms are required to extract the contaminants. For example – municipal wastewater. In these special cases, the process of bioaugmentation is used. There's only one major drawback in this process. It almost becomes impossible to control the growth of microorganisms in the process of removing the particular contaminant	**Bioreactors**: it involves the processing of contaminated solid material (soil, sediment, sludge) or water through an engineered containment system.
Intrinsic Bioremediation - The process of intrinsic bioremediation is most effective in the soil and water because of these two biomes which always have a high probability of being full of contaminants and toxins. The process of intrinsic bioremediation is mostly used in underground places like underground petroleum tanks. In such a place, it is difficult to detect a leakage and contaminants and toxins can find their way to enter through these leaks and contaminate the petrol. Thus, only microorganisms can remove the toxins and clean the tanks.	**Composting**: Composting is nature's process of recycling decomposed organic materials into a rich soil known as compost

1.4.7 PHYTOREMEDIATION

In this scenario, plants are directly used to clean up or contain contaminants in the soil. This method of bioremediation will help mitigate the environmental problem without the need to excavate the contaminant material and dispose of it elsewhere.

E.g:- Poplar trees are used for removal of toxic substances from ground(often used in USA)

Also radioactive elements have been phytoremediation using Sunflower plants

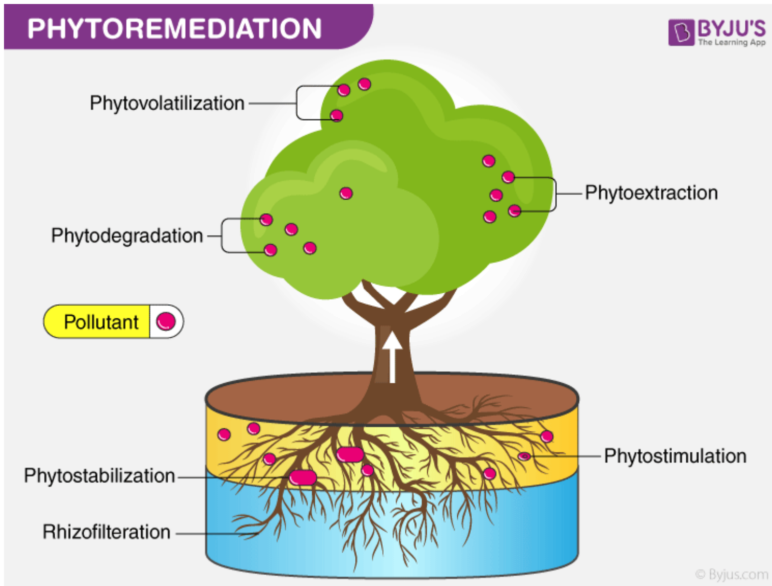


Fig: 1.11 Phytoremediation Technique

(Image source: Byjus)

1.5 OTHER APPLICATIONS OF BIOTECHNOLOGY

(a) Fermentation is an ancient invention of biotechnology. Alcohol and bread have been produced for ages with the help of microorganisms such as yeast. In today's scenario, the cultures have been purified and genetically refined to produce high-quality food products.

(b) Crop improvement by crossing the plant breeds with desired traits is another application of biotechnology in the agriculture sector.

(c) Transgenic plants are genetically engineered to produce plants with desired characteristics.

(d) Tissue culture is another application of biotechnology to produce a large number of plants with an explanation. It also helps in increasing the number of endangered plant species.

(e) It is also helpful in forensics for the identification of criminals, or paternity disputes.

1.5.1 BIOTECHNOLOGY AND ETHICS

The manipulation of living organisms by the human race has been subject to questioning especially regarding moral and ethical issues. Thus it cannot go on any further, without regulation. **Some ethical standards** are required to evaluate the morality of all human activities that might help or harm living organisms.

Going beyond the morality of such issues, the biological significance of such things is also important. Genetic modification of organisms can have unprecedented and unpredictable results when such organisms are introduced into the ecosystem.

It is essential that biotechnology innovations cautiously tested and analyzed before they are released for commercial use. Some methods like Clinical trials and government regulation help us to ensure that the products of Biotechnology that are released into the market are safe and effective. However, sometimes new information becomes available that makes companies and government agencies reconsider the safety or utility of innovation. This happens at times when a medication is occasionally withdrawn from the market. Apart from this certain biological Innovation and nobody technique of knowledge which raise ethical questions about the use of these methodologies.

Privacy is one of the most important concerns arising out of it. Should a health insurance company be able to charge you more if you have a gene variant that makes you likely to develop a disease? How would you feel if your school or employer had access to your genome?

There are also concerns about **safety, health effects, and ecological concerns related to technology** such as those associated with genetically engineered crops.

Therefore, under the **Environment Protection Act (1986),** the Government of India has set up organizations such as **GEAC (Genetic Engineering Appraisal Committee**), which will make decisions regarding the validity of G.M. research and the safety of introducing GM-organisms for public services.

The modification/usage of living organisms for public services (as food and medicine sources, for example) has also created problems with patents granted for the same. There is growing public anger towards certain companies being granted patents for products and technologies which make use of the genetic materials, plants, and other biological resources that have long been identified, developed, and used by farmers and indigenous people of a specific region/country.

Rice is an important food grain, the presence of which goes back thousands of years in Asia's agricultural history. There are an estimated 200,000 varieties of rice in India alone. The diversity of rice in India is one of the richest in the world. Basmati rice is distinct for its unique aroma and flavor, and 27 documented varieties of Basmati are grown in India. There is a reference to Basmati in ancient texts, folklore, and poetry, as it has been grown for centuries. In 1997, an American company got patent rights on Basmati rice through the U.S. Patent and Trademark Office. This allowed the company to sell a 'new' variety of Basmati, in the U.S. and abroad. This 'new' variety of Basmati had been derived from Indian farmer's varieties. Indian Basmati was crossed with semi-dwarf varieties and claimed as an invention or a novelty. The patent extends to functional equivalents, implying that other people selling Basmati rice could be restricted by the patent.

Several attempts have also been made to patent uses, products, and processes based on Indian traditional herbal medicines, e.g., turmeric neem. If we are not vigilant and we do not immediately counter these patent applications, other countries/individuals may encash on our rich legacy, and we may not be able to do anything about it

i. Biopiracy

Biopiracy is the term used to refer to the use of bio-resources by multinational companies and other organizations without proper authorization from the countries and people concerned without compensatory payment.

Most of the industrialized nations are rich financially but poor in **biodiversity and traditional knowledge**. In contrast, the developing and the underdeveloped world is rich in biodiversity and traditional knowledge related to bio-resources.

Traditional knowledge related to bio-resources can be exploited to develop modern applications and can also be used to save time, effort, and expenditure during their commercialization.

There has been a growing realization of the injustice, inadequate compensation, and benefit-sharing between developed and developing countries. Therefore, some nations are developing laws to prevent such unauthorized exploitation of their bio-resources and traditional knowledge.

1.6 SCOPE OF BIOTECHNOLOGY

Biotechnology is applied to various fields and many industries such as food, pharmaceuticals, medicine, agriculture, etc.. It has its scope in both research and engineering.

Genetic engineering has helped in the production of therapeutic proteins as well as biological organisms. Biotechnology has made major advances in molecular biology and industrial biotechnology.

The scope of biotechnology is extended to various branches of Biology. Some of these include tissue culture, development of transgenic plants and animals, development of antibodies, etc. The USA itself has established more than 200 companies such as Biogen, Cetus, Hybritech, etc.

i. GENETICALLY ENGINEERED ORGANISMS

"Genetically modified organisms are those that have their DNA altered in some way through genetic engineering."

(Image source: alltop.com)

Genetically modified organisms (GMOs) or transgenic organisms are those in which DNA from the desired organism is inserted in the laboratory. They are created in the laboratory using scientific methods reproductive cloning or Recombinant DNA technology.

ii. Bt CROPS

<u>Definition</u>**:- Bt crops are transgenic crops that are genetically engineered from the DNA of bacterium Bacillus thuringiensis.**

Bt Crops are transgenic crops that produce the same toxin as the bacterium Bacillus thuringiensis in the plant cell, thereby, protecting the crops from pests. The bacterium secretes specific proteins known as "cry proteins" that are toxic to insects. A few of the Bt crops include cotton, brinjal, corn, etc.

When an insect feeds on the transgenic plants, the toxic cry protein present in the plants crystallizes the digestive system of insects that leads to the death of the organism. However, it has no harmful effects on the human digestive system.

iii. TYPES OF Bt CROPS:

Bt Cotton

- The Bt cotton variety is genetically transformed with the Bt gene to protect the plants from bollworm, a major pest of cotton.
- The worms present on the leaves of Bt cotton become lethargic and sleepy and thus, cause less damage to the plants. The toxic proteins produced by the crops are ingested by the pests which kill them, thereby, protecting the crops.

Bt Brinjal

- Bt brinjal is also produced by genetic transformation of a crystal protein gene cry 1 Ac from the bacterium Bacillus thuringiensis. Bt brinjal was developed to provide resistance against lepidopteran insects.
- The proteins produced by Bt genes bind to the receptors present on the insect's membrane, which forms pores on the membranes. This disrupts the digestive process and leads to the death of the insect

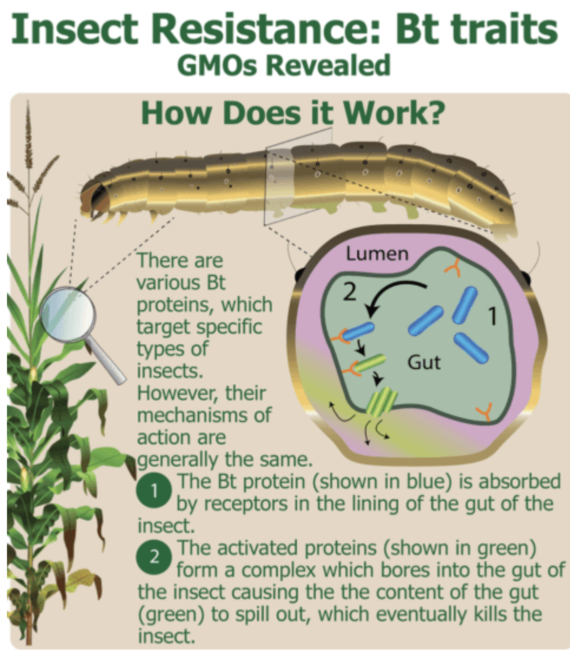


Fig:1.12 Bt Crops (Mechanism)

(Image source: Biofortified.org)

iv. Advantages of Bt crops

Following are the major advantages of Bt crops:

- It helps in improving the crop yield, thereby raising the farmer's income. This results in increased farm production.
- They help in controlling soil pollution as the use of synthetic pesticides is reduced.
- Bt crops help in protecting beneficial insects.
- It can easily feed an increasing population due to increased yields in a short time.
- It leads to the production of disease-free crops owing to the reduction of pesticides.
- It leads to more productivity in a small area of land.

v. Disadvantages of Bt Crops

Bt crops have a few disadvantages as well:

- Bt crops are costlier than naturally grown crops.
- It can disrupt the natural process of gene flow.
- The pests might become resistant to the toxins produced by these crops, and the crop production might decline.

- Threats to traditional knowledge and farming practices due to increased competitiveness from big capitalist
- Seed Monopolies by big companies
- Issues of Seed survival after the first generation

vi. Monsanto Genetically Modified Corn

Monsanto's genetically modified Bt corn is having its roots munched by super-rootworms and other superbugs, putting corn crops at risk. Yet, more evidence is found of the dangers to human health. The strain of corn, engineered to kill the larvae of beetles, such as the corn rootworm, contains a gene copied from an insect-killing bacteria called Bacillus thuringiensis, or Bt. Monsanto's G.M. Bt corn is equipped with a gene from soil bacteria called Bt or Bacillus thuringiensis. This produces the Bt-toxin in the corn. The pesticide breaks open the stomach of certain insects and kill them.

This Bt corn was introduced into the food supply in the late 1990s, and problems have been occurring ever since. However, the Environmental Protection Agency (EPA) was warning against this variety due to apprehensions about ill effects on the environment and human health. Monsanto and the EPA swore that the genetically engineered corn would only harm insects. They stated that the Bt-toxin produced inside the plant would be destroyed in the human digestive system. They said it would not have any impact on the health of consumers. Unfortunately, they have been proven wrong, because not only is Bt corn producing resistant "super pests", researchers have also found that the Bt-toxin can badly affect human health.

vii. Issues with Bt Cotton

- It is an insect-resistant transgenic crop that is designed to combat the **bollworm**.
- Bt cotton was created through genetic alteration of the cotton genome to express a microbial protein from the bacterium Bacillus thuringiensis.
- In short, the transgene inserted into the plant's genome produces toxin crystals that the plant would not normally produce which, when ingested by a certain population of organisms, dissolves the gut lining, leading to the organism's death.

- Although the Bollgard 2 technology for cotton was supposed to protect crops against the pink bollworm, **the pest has grown resistant to the toxins produced by this trait only in India.**
- It is argued by research and scientific lobby that Bt-cotton seeds are not suitable under Monsoon conditions and unlike other Cotton-growing countries where open-pollinated cotton varieties are grown, Indian cotton farmers only opt for hybrid varieties.

viii. Recent developments

GM Mustard

Dhara Mustard Hybrid-11, otherwise known as DMH - 11, is a genetically modified hybrid variety of the mustard species Brassica juncea. It was developed by Professor Deepak Pental from the University of Delhi, to reduce India's demand for edible oil imports. DMH - 11 was created through transgenic technology, primarily involving the Bar, Barnase, and Barnstar gene system. The Barnase gene confers male sterility, while the Barnstar gene restores DMH - 11's ability to produce fertile seeds. The insertion of the third gene Bar enables DMH - 11 to produce phosphinothricin-N- acetyl-transferase, the enzyme responsible for Glufosinate resistance.

This hybrid mustard variety has come under intense public scrutiny, mainly due to concerns regarding DMH - 11's potential to affect the environment as well as consumer health adversely. DMH - 11 was found not to pose any food allergy risks, and has demonstrated increased yields over existing mustard varieties. Conflicting details and results regarding the field trials and safety evaluations conducted on DMH - 11 have delayed its approval for commercial cropping.

Fig:1.13 GMO Crops worldwide

(Image Source: isaaa.org)

1.7 VACCINES

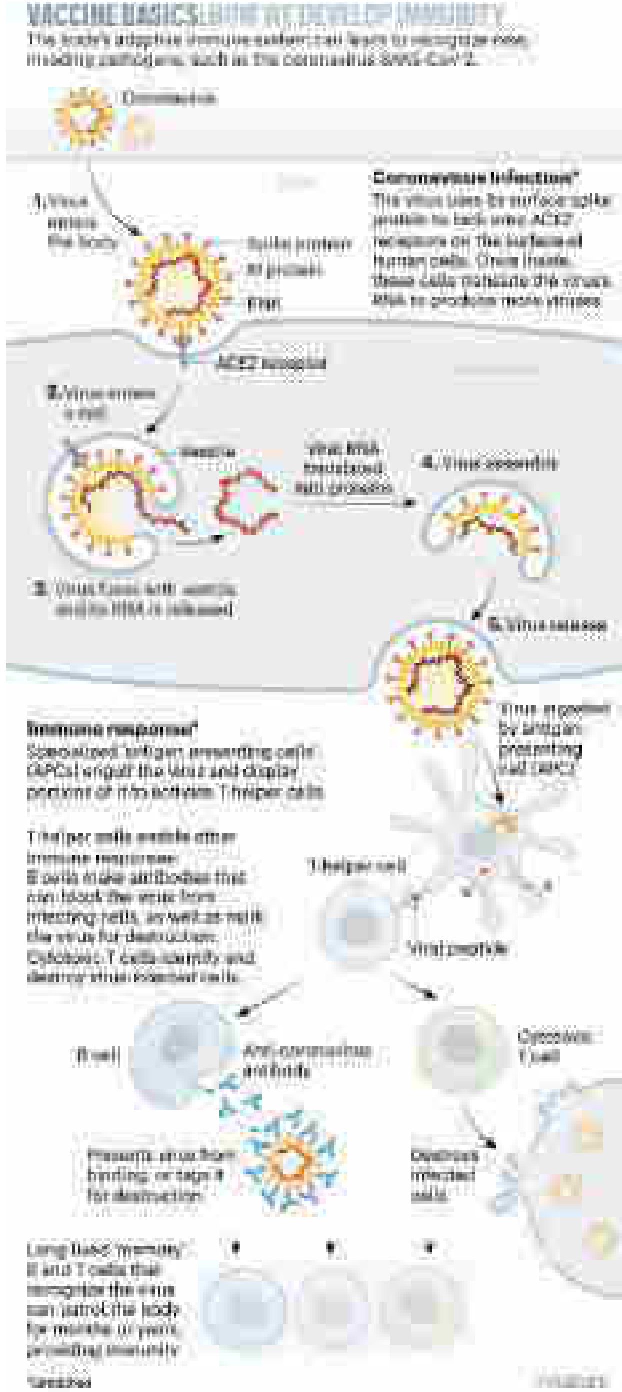
DNA Vaccines

- DNA vaccination is a technique for protecting an animal against disease by injecting it with genetically engineered DNA, so cells directly produce an antigen, resulting in a protective immunological response.
- Several DNA vaccines have been released for veterinary use, and there has been promising research using the vaccines for viral, bacterial and parasitic diseases, as well as to several tumour types.
- Although only one DNA vaccine has been approved for human use, DNA vaccines may have several potential advantages over conventional vaccines, including the ability to induce a wider range of immune response types.

- Field of DNA vaccination is developing very rapidly, the vaccines that are being developed use not only DNA but also the adjuncts that assist DNA target specific cells Or that may Act as adjuvants in stimulating or directing the immune response.
- However, there are still several aspects of the development and functioning of DNA vaccines that are yet not understood properly. Still, it has not impeded the research and further progress towards working on its development.
- The first such vaccines that have been approved for use are likely to utilize plasmid DNA from bacterial cells. In future, it is believed that the vaccines mainly use RNA derived molecules or nucleic acid molecules.

Other Types of Vaccines

In the wake of Coronavirus Pandemic, vaccine Development has taken a front seat in the global research community. Several Nations have been in the vaccine Development Programme and many who are not actively involved are supporting the initiatives by way of manpower, funding, logistics etc.More than 90 vaccines are being developed against SARS-CoV-2 by research teams in companies and universities across the world. Researchers are trialling different technologies, some of which haven't been used in a licensed vaccine before. All vaccines aim to expose the body to an antigen that won't cause disease, but will provoke an immune response that can block or kill the virus if a person becomes infected. There are at least eight types being tried against the coronavirus, and they rely on different viruses or viral parts.



(Image source: NATURE)

i. Virus Vaccines

These vaccines are developed using the virus itself, in an inactivated or weakened form. Many existing vaccines are made in this way, such as those against measles and polio, but they require extensive safety testing.

In a **weakened vaccine**, the virus which is being used is passed through human or animal cells until it picks up mutations that make it less potent to cause diseases.

In the case of **Inactivated Vaccine**, the virus is rendered uninfectious using chemicals such as formaldehyde or heat.

Viral Vector Vaccines:

In viral Vector Vaccines, the virus is Genetically engineered so that it can produce proteins in the body. They are gradually weakened so that they can't cause any disease.

There are two types of viral Vector Vaccines:-

Replicating Viral Vector Vaccines: The recently developed Ebola Vaccine is an example of this; which replicates within cells. These Vaccines are safe and provoke strong immune responses.

Non replicating Viral Vector: These Vaccines have been useful in heme therapy. They utilize booster shots to induce long-lasting immunity.

ii. Nucleic Acid Vaccines

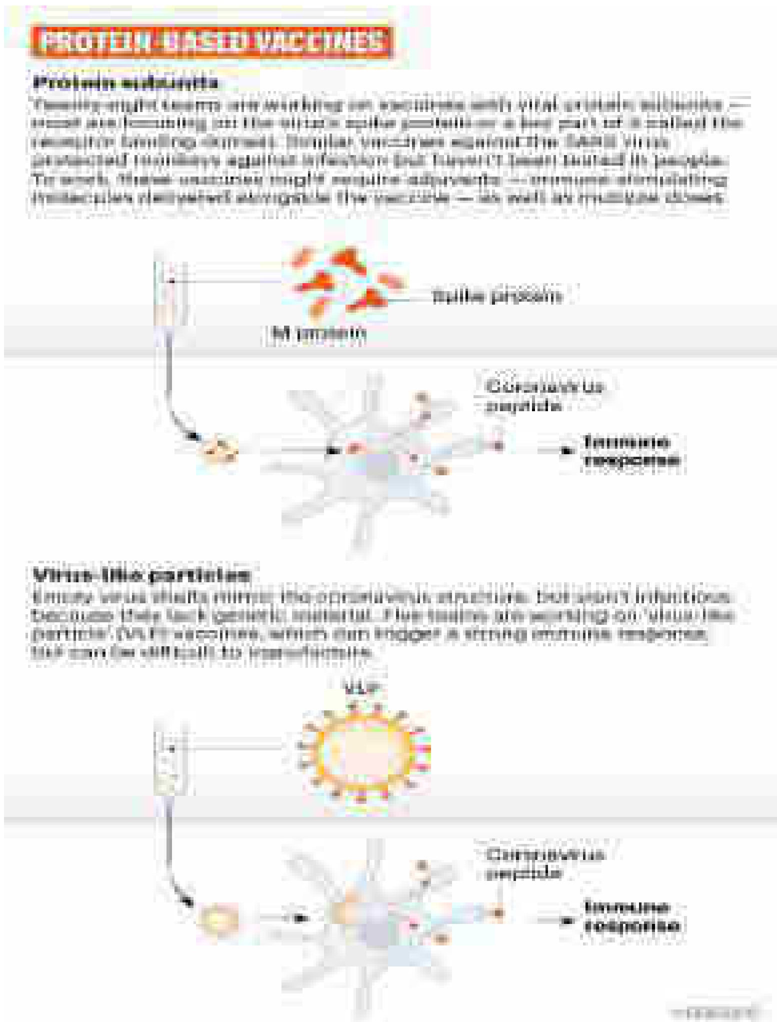
In these Vaccines, the nucleic acid is inserted into human cells, which then churn out copies of the virus protein; most of these vaccines encode the virus's spike protein.

There are **DNA Vaccines** that use the process of electroporation for creating pores membranes to increase the uptake of DNA into cells. While the **RNA Vaccines** are encased in lipid coats so that it can enter cells.

Both DNA and RNA Vaccines are easy to develop as their production involves alterations in genetic material only and not the viruses. However, they are unproven.

iii. Protein-Based Vaccines

In these Vaccines fragments of protein or protein shells that mimic the virus are inserted. Two versions of these Vaccines are generally under trial; one uses Protein subunits while the other version uses Virus-like particles.



(Image source:Nature)

iv. STAGES OF VACCINE DEVELOPMENT

It is often seen that in almost all the regulatory regimes, vaccine development takes several years and typically proceeds through three phases of clinical trials.

Phase 1: In this phase, trial Vaccine is administered to Small groups of people.

Phase 2: During this phase, Clinical study is extended and the vaccine is administered to people who have characteristics (like physical health and age) similar to those people for whom the new vaccine is intended.

Phase 3: In this phase Vaccine is given to a large pool of people and its efficacy and safety are tested. During this phase, participants who engage in trials either receive the vaccine or a placebo.

Note:- Placebo is something that looks similar to real treatment but it is not. For example- sugar pills and saline injections.

The effectiveness of Vaccines is analyzed after comparing the prevalence of infection in the group that was given the vaccine with the one which received a placebo.

The hypothesis that those in the vaccine group will be infected significantly less is thus tested.

1.7.1 BIOINFORMATICS

Bioinformatics is an emerging branch of biological science that emerged by the combination of both biology and information technology. It is an interdisciplinary field of study that uses Biology, Chemistry, Mathematics, Statistics, and Computer Science that are merged to form a single discipline. This sector is mainly involved in analyzing biological data, developing new software using biological tools.

According to the NCBI- National Center for Biotechnology Information, the branch of NLM- National Library of Medicine and NIH- National Institutes of Health, defines **Bioinformatics as the analysis, collection, classification, manipulation, recovery, storage and visualization of all biological information using computation technology.**

v. Applications of BIOINFORMATICS

Few of the Applications of Bioinformatics are:

- In Gene therapy.
- In Evolutionary studies.
- In Microbial applications.
- In Prediction of Protein Structure.
- For the Storage and Retrieval of Data.
- In the field of medicine, used in the discovery of new drugs.
- In Biometrical Analysis for identification and access control for improvising crop management, crop production, and pest control.

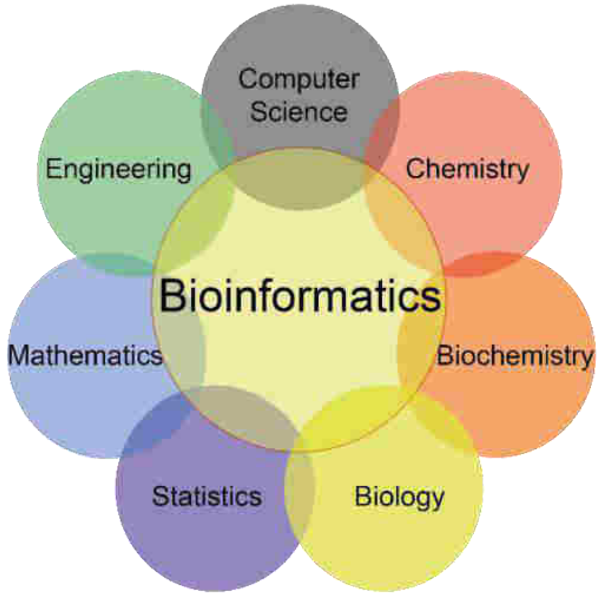


Fig: 1.14 Bioinformatics

(Image *Source:techgetz.com)*

Bioinformatics is mainly used to extract knowledge from biological data through the development of algorithms and software.	A significant application of bioinformatics can be found in the fields of precision and preventive medicines, which is mainly focused on developing measures to prevent, control and cure dreadful infectious diseases.
Bioinformatics is widely applied in the examination of Genomics, Proteomics, 3D structure modelling of Proteins, Image analysis, Drug designing and a lot more	The main aim of Bioinformatics is to increase the understanding of biological processes.

1.7.2 EPIDEMIOLOGY

Epidemiology is the study of the distribution and determinants of health-related status among specific populations and the application of that study to the control of health problems.

Aims and Objectives of Epidemiology Study:

- Discover the agent, host, and environmental factors that affect health
- Determine the relative importance of causes of illness, disability, and death
- Identify those segments of the population that have the greatest risk from specific causes of ill health
- Evaluate the effectiveness of health programs and services in improving population health.

1.7.3 BIOSIGNATURE

A biosignature can be defined as any substance like isotope, molecules, among others, or phenomenon that provides scientific evidence of past or present life. Certain attributes of life that can be measured include its complex physical or chemical structures and its use of free energy and the production of biomass and wastes.

A biosignature can provide evidence for living organisms outside the Earth and can be directly or indirectly detected by searching for their unique byproducts.

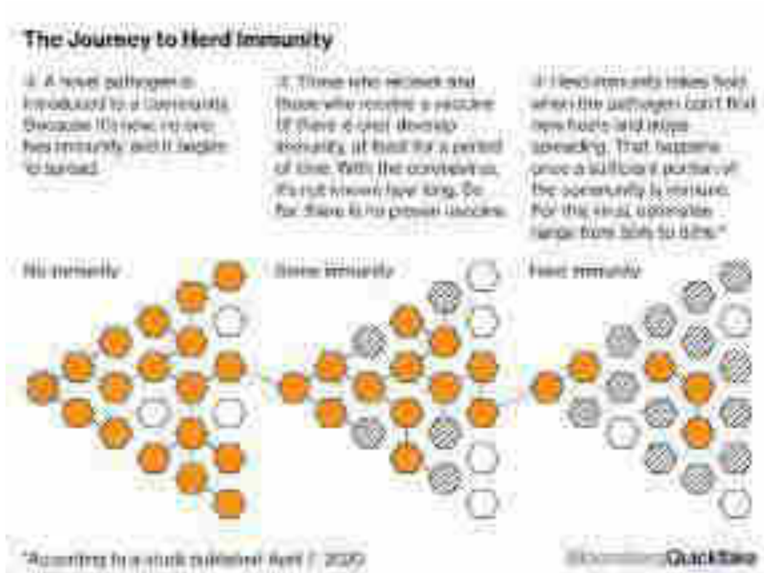
For example, the presence of methane in the atmosphere of Mars is an area of ongoing research and a highly contentious subject. Because it tends to be destroyed in the atmosphere by photochemistry, the presence of excess methane on a planet can be an indication that there must be an active source. With life being the strongest source of methane on Earth, observing a disequilibrium in the methane abundance on another planet could be a viable biosignature.

1.7.4 HERD IMMUNITY

Herd immunity is a concept that is generally described in the context of a vaccine. Herd immunity refers to preventing an infectious disease from spreading by immunizing a certain percentage of the population. While the concept is most commonly used in the context of vaccination, herd immunity can also be achieved when enough people have become immune after being infected. The basic process behind this is If some percentage of the population gets immune, then members of that population who get infection can no longer infect another person. In this way, the chain of infection will be broken through the community ("herd"), and it will prevent the disease from reaching those who are the most vulnerable.

Generally, there are two ways of attaining herd immunity:-

- Firstly, through mass vaccinations
- Secondly, through the infection when a person gets infected and after a while, they develop antibodies to fight the infection and thus become immune to it



(Image source: Bloomberg)

<u>Issues and Concerns Related To Herd Immunity:</u>

In case of any disease which does not have a vaccine like that of Coronavirus, development of herd immunity right away would be a dangerous strategy. This will result in a large number of people getting ill which in turn would burden the entire health system. More so, the effectiveness of herd immunity also depends upon the population structure of the country.

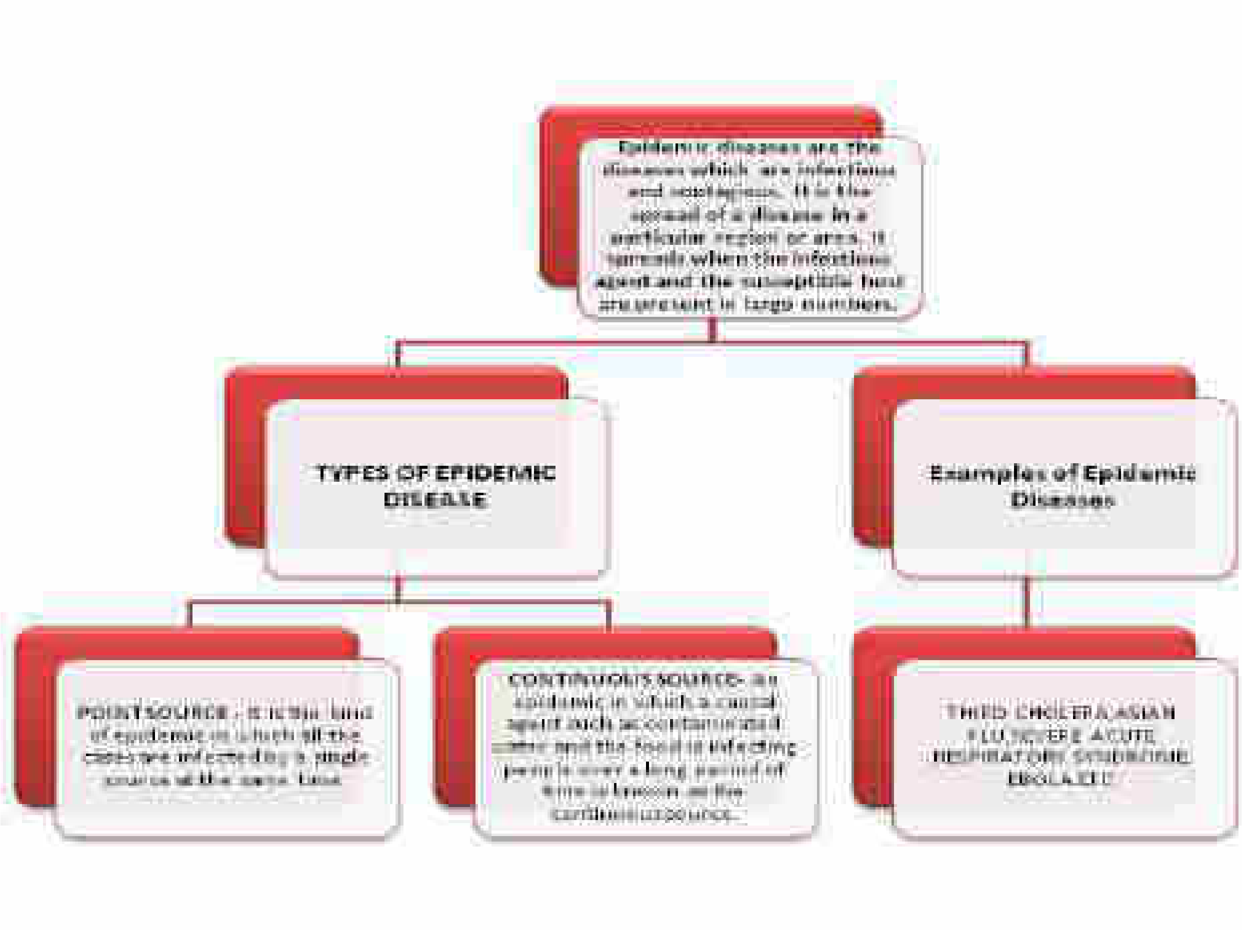
1.7.5 Some Important Terms Associated With Diseases

ENDEMIC DISEASE

An endemic disease is the one that is always present in a population, for eg., chicken pox, malaria. Endemic diseases are relatively rare and not as widespread as an epidemic. It is always prevalent in the population that lives in that area. These areas contain viruses, bacteria or parasites which can transmit the diseases to humans. There are two types of endemic diseases:

- **Holoendemic Diseases**- This kind of endemic disease affects mostly children. This infection is highly prevalent in the early years of life. The adult population do not show traces of diseases as much as children do. Malaria is a type of holoendemic disease.
- **Hyperendemic Diseases-** These type of endemic diseases are constantly present at a high rate and are found among all age groups equally

EPIDEMIC DISEASE



PANDEMIC DISEASE -A pandemic disease is an epidemic that has spread across a large area such as multiple continents or worldwide. HIV/AIDS is one of the most destructive pandemic diseases that broke out all over the world. Influenza is another pandemic disease and has occurred more than once. The pandemic is caused by a new infectious agent that has never caused a disease before. It has faced a larger death toll than the epidemic diseases. Antibiotic resistance and increased travel and mobility have increased the risk of diseases among humans.

1.8 GENETIC ENGINEERING APPRAISAL COMMITTEE (GEAC)

The GEAC is India's apex biotechnology regulatory body.

It is a statutory body constituted under the

'Rules for the Manufacture,Use /Import /Export and Storage of Hazardous Microorganisms/Genetically Engineering Organisms or Cells, 1989' notified under the Environment (Protection) Act, 1986.

- It was formed as the Genetic Engineering Approval Committee and was renamed to its current name in 2010.
- It functions under the Ministry of Environment, Forests & Climate Change.
- The body regulates the use, manufacture, storage, import and export of hazardous microorganisms or genetically-engineered organisms and cells in India.

Functions of GEAC

Composition of GEAC

- The Committee is chaired by the Special Secretary/Additional Secretary of the Ministry of Environment, Forests and Climate Change, GOI.
- A representative of the Department of Biotechnology is a co-chair.
- There are many other members who meet every month to review the applications in the Committee's domain. The members include experts from other ministries as well as institutions such as the ICAR, ICMR, CCMB, etc.

1.9 MISCELLANEOUS

RECENT DEVELOPMENTS RELATED TO BIOTECHNOLOGY

Gene Editing and CRISPR/CaS-9:-

Genome editing, also known as gene editing, is a kind of genetic engineering where the DNA is deleted, inserted or replaced in an organism's genome. generally molecular **scissors'** or **'engineered nucleases',**are used in this technology.

These scissors make double-strand breaks (DSBs) at specific sites in the genome and these breaks are repaired by homologous recombination (HR) or nonhomologous end-joining (NHEJ). This results in targeted mutations or 'edits'.

At present, there are four kinds of engineered nucleases namely, meganucleases, transcription activator-like effector-based nucleases (TALEN), zinc finger nucleases (ZFNs) and **CRISPR/Cas9 systems.**

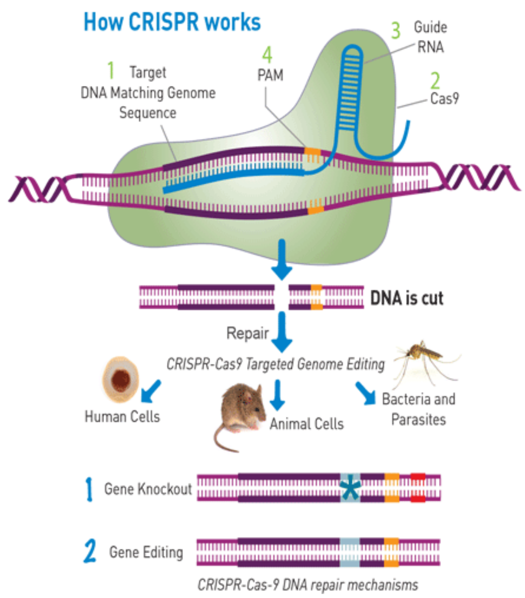


Fig: 1.15 Genome editing

(Image source: science direct)

1.10 About CRISPR-CaS 9

It was a scientist named- **He Jiankui , a Chinese, who shocked the scientific community in 2018 after announcing he had successfully altered the genes of twin girls born in November to prevent them from contracting HIV.**

He had "privately" organised a project team that included foreign staff and used "technology of uncertain safety and effectiveness" for illegal human embryo gene-editing, investigators said. But such gene-editing work is banned in most countries, including China.

Cutting-and-pasting DNA (CRISPR-CAS9)

- The newly developed technology allows scientists to essentially cut-and-paste DNA, which may be used for genetic fixes to cure or treat disease.
- However, there are also safety and ethical concerns about this technology like ;CRISPR allows us to target nearly any genomic location and potentially repair broken genes. It can remove, add or alter specific DNA sequences in the genome of higher organisms.

How does it work?

- Unusual but repeated DNA structures that scientists had been observing for some time were given a name. This name assigned was “Clustered regularly interspaced short palindromic repeats” or CRISPR.
- It was discovered in the year 2012, that CRISPR is a key part of the “immune system”.

The CRISPR-Cas9 gene-editing tool thus has two components. They are:

A sequence of short RNA that can bind to a specific target of the DNA	An enzyme called CaS 9 ,which acts as molecular scissors to cut the DNA.

- To edit a gene of interest, the short RNA sequence that perfectly matches with the DNA sequence that has to be edited is introduced. Once it binds to the DNA, the Cas9 enzyme cuts the DNA at the targeted location where the RNA sequence is bound.
- Once the DNA is cut, the natural DNA repair mechanism is utilized to add or remove genetic material or make changes to the DNA.

Advantages of Gene editing	Disadvantages of Gene Editing
● CRISPR could be used to modify disease-causing genes in embryos brought to term, removing the faulty script from the genetic code of that person’s future descendants as well. ● Genome editing (Gene editing) could potentially decrease, or even eliminate, the incidence of many serious genetic diseases, reducing human suffering worldwide. ● It might also be possible to install genes that offer lifelong protection against infection.	● Making irreversible changes to every cell in the bodies of future children and all their descendants would constitute extraordinarily risky human experimentation. ● Making irreversible changes to every cell in the bodies of future children and all their descendants would constitute extraordinarily risky human experimentation. ● There are issues including off-target mutations (unintentional edits to the genome), persistent editing effects,

• CRISPR May Prove Useful in De-Extinction Efforts. For example,Researchers are using the powerfula gene-editing tool to recreate the woolly mammoth. • CRISPR Could Create New, Healthier Foods: In agricultural crops, Crispr has the potential to impact yield, disease resistance, taste, and other traits. Few experiments have been done. If successful it can help us to eradicate the problem of hunger and malnutrition.	genetic mechanisms in embryonic and fetal development, and longer-term health and safety consequences. • There are issues including off-target mutations (unintentional edits to the genome), persistent editing effects, genetic mechanisms in embryonic and fetal development, and longer-term health and safety consequences. • Altering one gene could have unforeseen and widespread effects on other parts of the genome hence it will become a tool for selecting desired characteristics such as intelligence and attractiveness. • It can also be used to eliminate dangerous species of pests and few experiments are being carried out on mosquitoes but eliminating a species, even one that doesn't appear to have much ecological value, could upset the careful balance of ecosystems. That could have disastrous consequences, such as disrupting the food web or increasing the risk that diseases like malaria could be spread by different species entirely.

Current scientific advancements show that CRISPR is not only an extremely versatile technology, it's proving to be precise and increasingly safe to use. But a lot of progress still has to be made; we are only beginning to see the full potential of genome-editing tools like CRISPR-Cas9.

Technological and ethical hurdles still stand between us and a future in which we feed the planet with engineered food, eliminate genetic disorders, or bring extinct animal species back to life.

MANAV : HUMAN ATLAS PROJECT

Recent times have witnessed an explosion in the amount of biological data generated. There are millions of research articles with pivotal information on human health and disease, spanning from single-molecule resolution to the level of the whole organism. However, this information is scattered in different databases, repositories, and in the text of journal articles.

This makes the seamless extraction of scientific information an extremely challenging and time-consuming (yet incomplete) process. With 100+ databases and millions of data points (combined) from just human cells/tissue and disease, there is a pressing need to collate this information in such a way that users like academic/industrial/clinical researcher as well as teachers and students can easily access information that is relevant to them from a common and modular platform.

Although there are ambitious ongoing efforts like the Recon X, The Virtual Physiological Human, Human Cell Atlas, none of these projects aim to build the map of the whole human body simultaneously comparing both macro(organ/tissue/cell) and micro (molecular interaction networks) level details.

- Manav-Human Atlas Initiative aims to construct a comprehensive map of the entire human body which will explicitly document macro to micro-level information.
- The project Manav will dramatically accelerate our understanding of the working of the human body and help design better therapeutic targets for treating diseases like cancer, diabetes, and more.
- This project will require understanding, extracting, and collating information from millions of scientific papers that would need a massive investment of time, effort, and manpower.

- The large pool of scientifically literate population in India pursuing a bachelors /masters / Ph.D. is a great resource that will be trained and engaged as part of this project to use the annotation tool being developed to collate, curate, manage and visualize this scientific information.
- This project is funded by the Department of Biotechnology (DBT), Government of India as a collaboration between Persistent Systems, NCCS, and IISER, Pune.
-

Fig;1.16 Human Atlas Project

(Image source:dbt.gov.in)

HUMAN GENOME PROJECT

The Human genome project (HGP) was an international scientific research project which was successfully completed in the year 2003 by sequencing the entire human genome of 3.3 billion base pairs. The HGP led to the growth of bioinformatics which is a vast field of research. The successful sequencing of the human genome could solve the mystery of many disorders in humans and gave us a way to cope up with them.

Goals of the human genome project

Goals of the human genome project include:

- Optimization of the data analysis.
- Sequencing the entire genome.
- Identification of the complete human genome.
- Creating genome sequence databases to store the data.
- Taking care of the legal, ethical and social issues that the project may pose.
- Methods of the human genome project
- In this project, two different and significant methods are typically used.

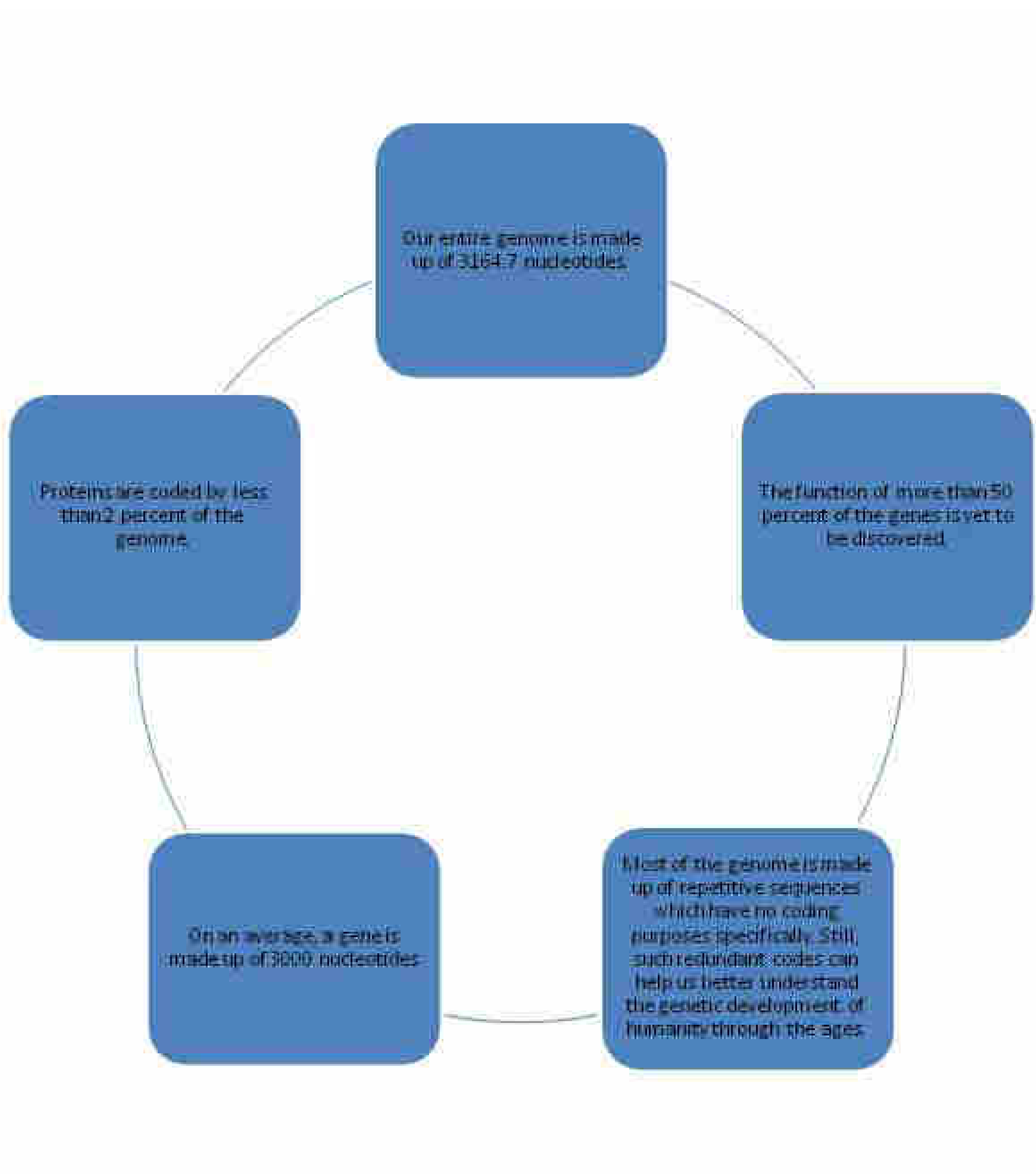
Process and method of Human Genome Project

- Expressed sequence tags wherein the genes were differentiated into the ones forming a part of the genome and the others which expressed RNAs.
- Sequence Annotation wherein the entire genome was first sequenced and the functional tags were assigned later.

Process

- The process of the human genome project
- The complete gene set was isolated from a cell.
- It was then split into small fragments.
- This DNA structure was then amplified with the help of a vector which mostly was BAC (Bacterial artificial chromosomes) and YAC (Yeast artificial chromosomes).
- The smaller fragments were then sequenced using DNA sequencers.
- On the basis of overlapping regions, the sequences were then arranged.
- All the information of this genome sequence was then stored in a computer-based program.
- This way the entire genome was sequenced and stored as a genome database in computers. Genome mapping was the next goal which was achieved with the help of microsatellites (repetitive DNA sequences).

Features of the project



Applications of Human Genome Project

As the goals of the human genome project were achieved, it led to great advancement in research. Today, if any disease arises due to some alteration in a certain gene, then it could be traced and compared to the genome database that we already have. In this way, a more rational step could be taken to deal with the problem and can be fixed with more ease.

Human Genome Project (write)

The Genome Project - Write (also known as GP-Write) is a large-scale collaborative research project an extension of Human Genome Project, that focuses on the development of technologies for the synthesis and testing of genomes of many different species of microbes, plants, and animals, including the human genome in a sub-project known as Human **Genome Project-Write (HGP-Write)**

Formally announced on 2 June 2016, the project leverages two decades of work on synthetic biology and artificial gene synthesis. The newly created HGP-Write project will be managed by the Center of Excellence for Engineering Biology, an American nonprofit organization. Researchers expect that the ability to artificially synthesize large portions of many genomes will result in many scientific and medical advances

A complete haploid copy of the human genome consists of at least three billion DNA nucleotide base pairs, which have been described in the **Human Genome Project - Read** program (95% completed as of 2004). Among the many goals of GP-Write is the making of cell lines resistant to all viruses and synthesis assembly lines to test variants of unknown significance that arise in research and diagnostic sequencing of human genomes (which has been exponentially improving in cost, quality, and interpretation).

BIOLOGICAL PESTICIDES

Biopesticides are certain types of pesticides derived from such natural materials as animals, plants, bacteria, and certain minerals. For example, canola oil and baking soda have pesticidal applications and are considered biopesticides. This process is also referred to a biological control. The biological application is mainly introduced to reduce the population of a pest and to produce pest-free yields. It is a self-sustaining and long-term treatment method, for managing invasive plants. The living organism applied in this system is used to suppress a weed infestation and to control pests including insects, pathogens, and grazing animals.

The natural enemies like parasitism, predation, and other mechanisms for controlling the plant pests are referred to as a biocontrol agent. They play an important role in controlling plant pests like nematodes, weeds, insects, and mites. The biological control agent helps in maintaining and balancing the plant species along with their natural enemies.

Agent	Target pest or weed
Microbial insecticides	
Bacteria	
Bacillus thuringiensis	Lepidoptera (moths/butterflies)
	Diptera (flies)
	Coleoptera (beetles)
Fungi	
Verticillium lecanii	Aphids and whiteflies
Metarhizium anisopliae	Spittlebugs
Metarhizium flavoviride	Locusts and grasshoppers
Beauveria bassiana	Colorado beetle
Virus	
Nuclear polyhedrosis	Various
[illegible]	
Mycoherbicides	
Colletotrichum gloeosporioides	Northern jointvetch (*Aeschynomene virginica*)
Colletotrichum orbiculare	Round-leaved mallow (*Malva pusilla*)
Phytophthora orbiculare	Milkweed vine (*Morrenia odorata*)
Alternaria cassiae	Sicklepod (*Cassia obtusifolia*)
Puccinia chondrillina	Skeleton weed (*Chondrilla juncea*)

Fig: 1.17 Examples of Biocontrol Agents

(imagesource: agriculture inindia.net)

Types of Biocontrol Agents

Biological control can be categorized into 2 types, namely inundated and classical.

Inundative BioControl	Classical biocontrol

This approach uses pathogens, where they are used to apply on a target weed at a very high rate in an aspect that is similar to herbicide application. The most common pathogens used in inundative biological control include nematodes and nuts. This approach does not prevent the invasive plant from implementing at a later date	It uses agent populations that would waver in a natural prey and predator relationship. This method adopts natural predators of the invasive plant to create an eternal relationship between a plant and biological control animals.

List of Biocontrol Agents:

Predators: They are mainly free-living species that consume prey in large numbers during their lifespan. Since the majority of insects constitute crop pests. Some of the predators include Lacewings, Spiders, Flies, Beetles, and dragonflies.

Pathogens: Virus, Bacteria, and fungi are relatively pathogenic micro-organisms that are host specifics or kill their host. Some of the microbial diseases occur naturally but they are used as biological pesticides.

Bacteria: Bacteria belonging to the coccobacillus group are more pathogenic to insects. They are used for biological control. They infect the digestive tract of insects thus limiting the options for controlling insects with sucking mouthparts namely scale insects and aphids.

Viruses: The use of insect virus as a controlling agent is still in inception. Since they are host specific, they turn out to have good potential as biocontrol agents.

Fungi: The fungi Entomophaga is effective against pests namely green peach aphid.

Parasitoids: They lay eggs in the body of the host (insect), eventually killing the host. It is later used as a source of food for the developing larva. It is one of the most widely used biological control agents.

Merits

- The biological control agents are environmentally friendly and cause no side effects.
- Less cost compared to other Agrochemicals – pesticides and insecticides.
- Easily available, easy to use and is effective throughout the season.
- Helps in reducing the use of chemicals and other pesticides.

Demerits

- It affects the product quality.
- Pest is not completely destroyed by these biological control agents.
- It is effective only for large scale

DNA FINGERPRINTING

It is defined as**" a technique that shows the genetic makeup of living things. It is a method of finding the difference between the satellite DNA regions in the genome**".

Satellite DNA regions are stretches of repetitive DNA which do not code for any specific protein. These non-coding sequences form a major chunk of the DNA profile of humans. They depict a high level of polymorphism and are the basis of DNA fingerprinting. These genes show a high level of polymorphism in all kinds of tissues as a result of which they prove to be very useful in forensic studies.

Any piece of DNA sample found at a crime scene can be analyzed for the level of polymorphism in the non-coding repetitive sequences. After the DNA profile is traced, it becomes easier to find the criminal by performing the DNA fingerprinting for the suspects.

Apart from crime scenes, Fingerprinting applications also prove useful in finding the parents of an unclaimed baby by conducting a paternity test on a DNA sample from the baby.

DNA Fingerprinting Steps

Alec Jeffreys developed this technique in which he used satellite DNAs also called VNTRs (Variable Number of Tandem Repeats) as a probe because it showed the high level of polymorphism.

Isolating the DNA.

↓

Digesting the DNA with the help of restriction endonuclease enzymes.

↓

Separating the digested fragments as per the fragment size by the process of electrophoresis.

↓

Blotting the separated fragments onto synthetic membranes like nylon.

↓

Hybridising the fragments using labelled VNTR probes.

↓

Analysing the hybrid fragments using autoradiography.

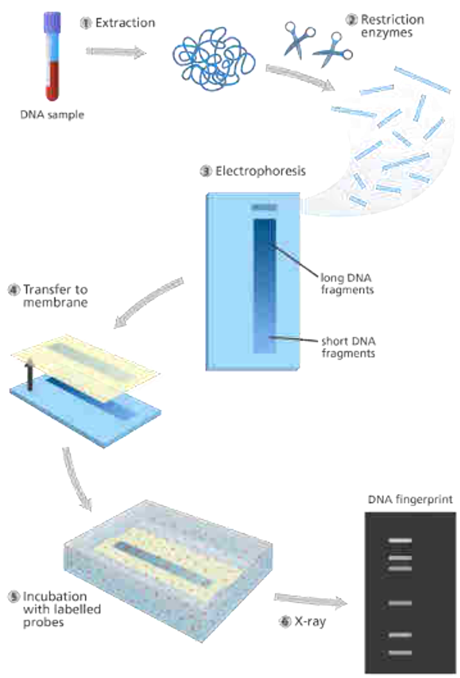


Fig: 1.18 Steps of DNA fingerprinting

(Image source: yourgenome)

Applications of DNA Fingerprinting

As discussed earlier the technique of fingerprinting is used for DNA analysis in forensic tests and paternity tests. Apart from these two fields, it is also used in determining the frequency of a particular gene in a population which gives rise to diversity. In case of the change in gene frequency or genetic drift, Fingerprinting can be used to trace the role of this change in evolution.

- Paternity and maternity
- Criminal identification and forensics
- Personal identification

STEM CELLS

Stem cells are" special human cells that can develop into many different types of cells, from muscle cells to brain cells."

Stem cells also have the ability to repair the damaged cells. These cells have strong healing power. They can evolve into any type of cell.

Research is going on and it is believed that stem cell therapies can cure ailments like paralysis and Alzheimer's as well.

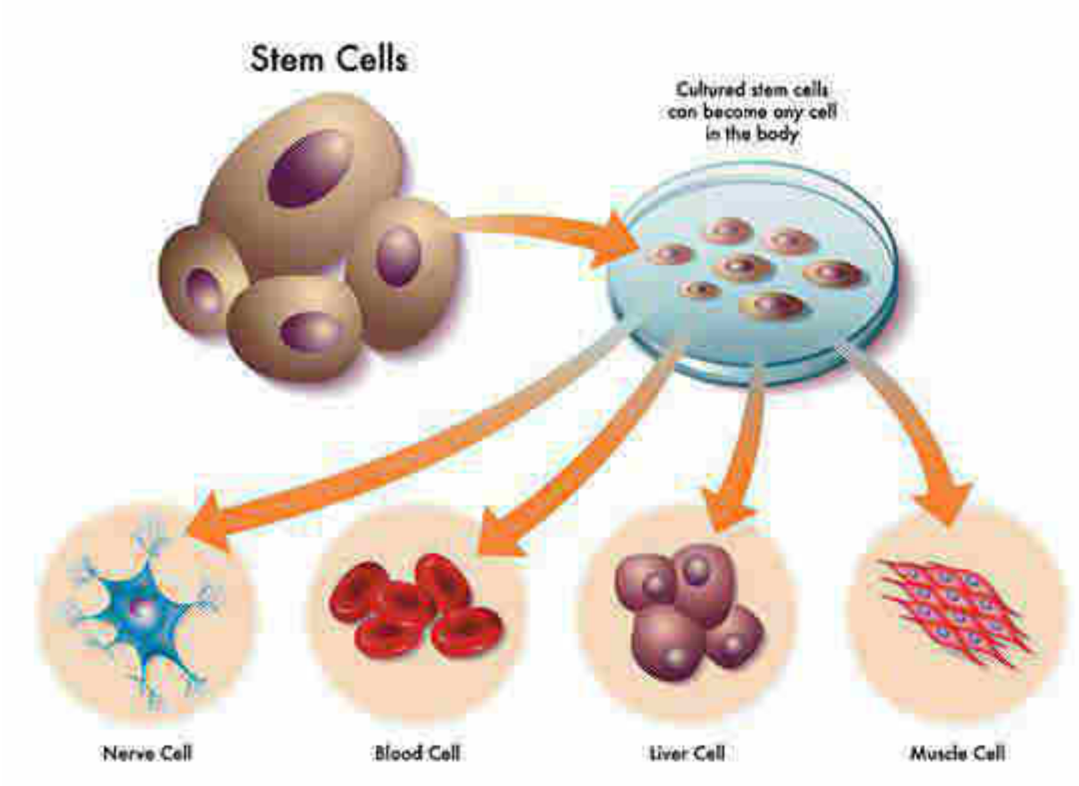


Fig:1.19 Stem cells

(Image source: Byjus.com)

Types of Stem Cells

Embryonic Stem Cells

The fertilized egg begins to divide immediately. All the cells in the young embryo are totipotent cells. These cells form a hollow structure within a few days. Cells in one region group together to form the inner cell mass. This contains pluripotent cells that make up the developing foetus.

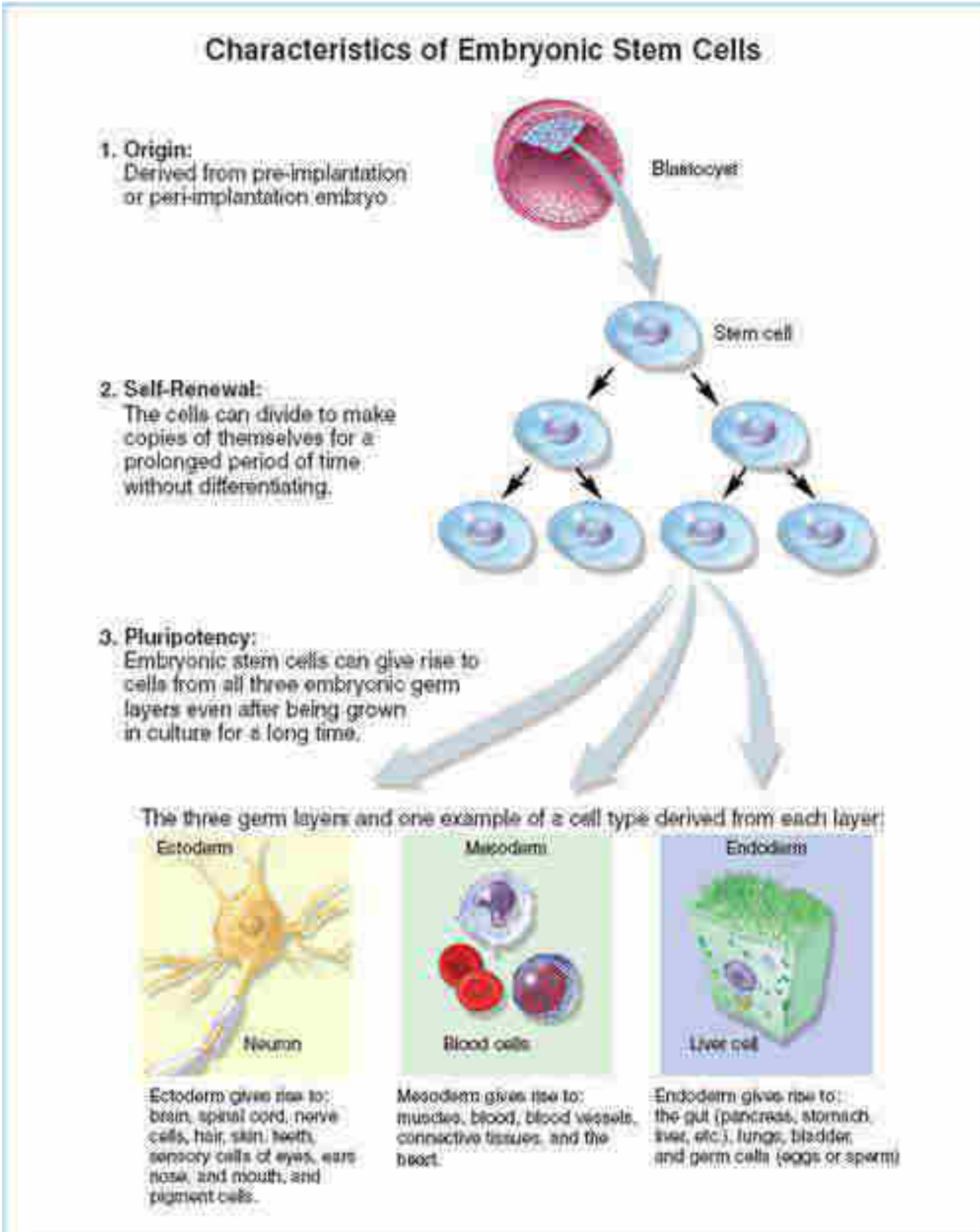


Fig :1.20 embryonic stem cells

(*Image source: Byjus.com)*

The embryonic stem cells can be further classified as:

Totipotent Stem Cells	**Pluripotent Stem Cells**	**Multipotent Stem Cells**	**Oligopotent Stem Cells**

These can differentiate into all possible types of stem cells	These are the cells from early embryos and can differentiate into any cell type.	These differentiate into a closely related cell type. For eg., the hematopoietic stem cells differentiate into red blood cells and white blood cells.	**Examples of oligopotent cells include**Adult lymphoid cells(any of the cells responsible for the production of immunity mediated by cells or antibodies and including lymphocytes, lymphoblasts, and plasma cells.) or myeloid cell that can differentiate into any of the blood stem cells found in the lymphatic system. They can differentiate into a few different types of cells.

Note:- Apart from above there are Unipotent Stem Cells: They can produce cells only of their own type. Since they have the ability to renew themselves, they are known as unipotent stem cells. For eg., Muscle stem cells

Adult Stem Cells:

These stem cells are obtained from developed organs and tissues. They can repair and replace the damaged tissues in the region where they are located. For eg., hematopoietic stem cells are found in the bone marrow. These stem cells are used in bone marrow transplants to treat specific types of cancers.

Induced Pluripotent Stem Cells:

These cells have been tested and arranged by converting tissue-specific cells into embryonic cells in the lab. These cells are accepted as an important tool to learn about normal development, onset and progression of the disease and also helpful in testing various drugs. These stem cells share the same characteristics as embryonic cells do. They also have the potential to give rise to all the different types of cells in the human body.

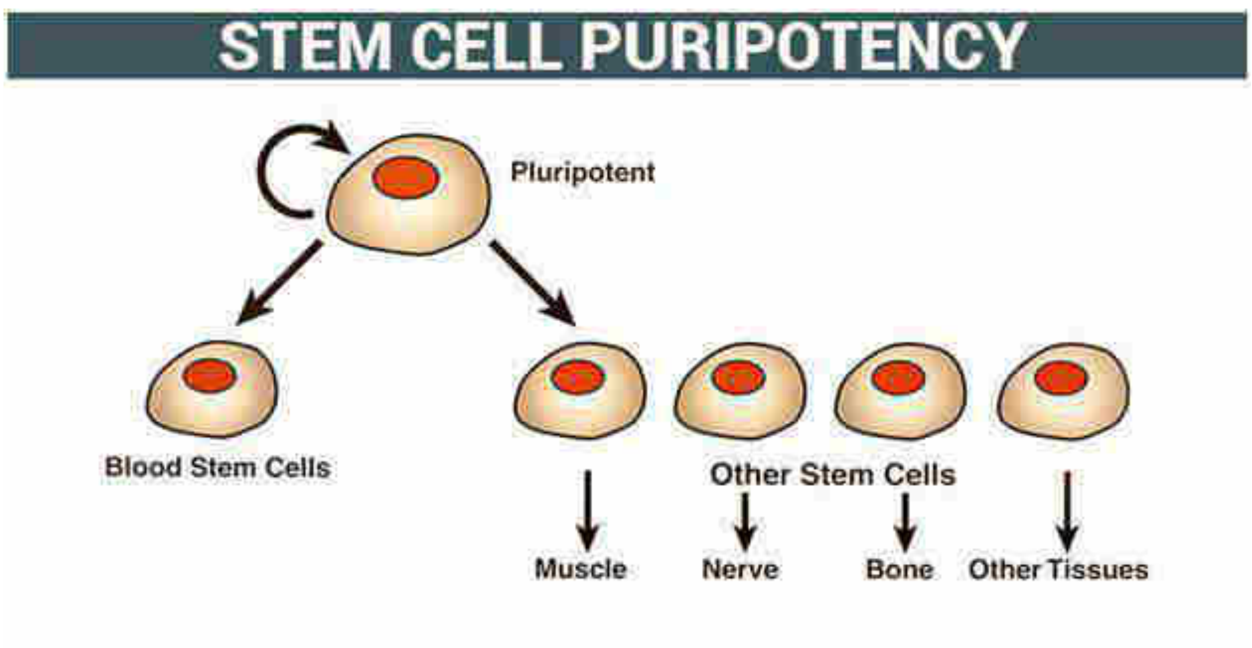


Fig: 1.21 Induced Pluripotent Stem Cells

(Image source: Byjus)

Mesenchymal Stem Cells:

These cells are mainly formed from the connective tissues surrounding other tissues and organs known as stroma. These mesenchymal stem cells are accurately called stromal cells. The first mesenchymal stem cells were found in the bone marrow that are capable of developing bones, fat cells, and cartilage.

There are different mesenchymal stem cells that are used to treat various diseases as they have been developed from different tissues of the human body. The characteristics of mesenchymal stem cells depend on the organ from where they originate.

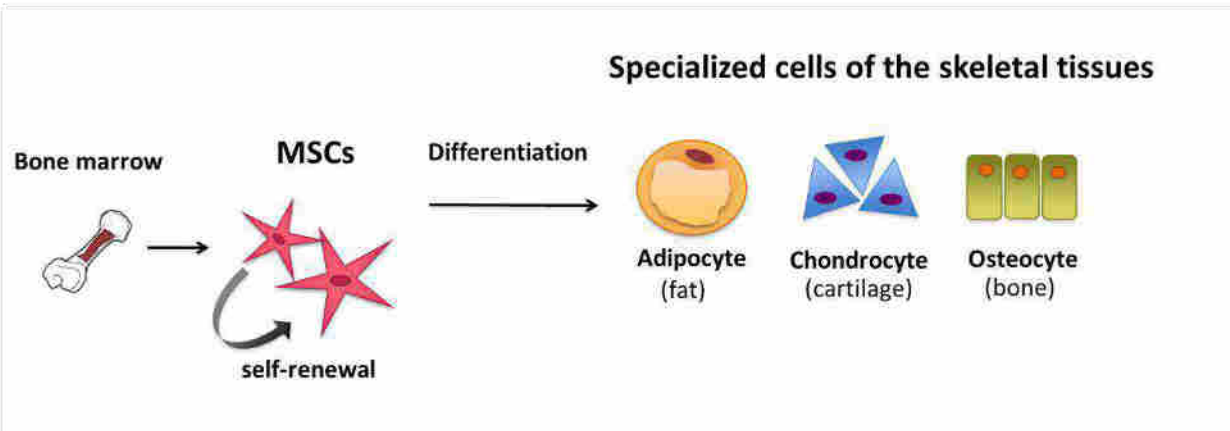


Fig:1.22 Mesenchymal stem cells

(Image source: Eurocell)

Applications of Stem Cells

Following are the important applications of stem cells:-

Tissue Regeneration	Cardiovascular diseases	Brain diseases treatment	Treatment of Blood Diseases
This is the most important application of stem cells. The stem cells can be used to grow a specific type of tissue or organ. This can be helpful in kidney and liver transplants. The	A team of researchers have developed blood vessels in mice using human stem cells. Within two weeks of implantation, the blood vessels formed their network and were as efficient as	Stem cells can also treat diseases such as Parkinson's disease and Alzheimer's. These can help to replenish the damaged brain cells. The researchers have tried to differentiate	The adult hematopoietic stem cells are used to treat cancers, sickle cell anaemia, and other immunodeficiency diseases. These stem cells can be used to produce red blood

doctors have already used the stem cells from beneath the epidermis to develop skin tissue that can repair severe burns or other injuries by tissue grafting.	the natural vessels.	embryonic stem cells into these types of cells. Therefore, it is possible to treat the diseases.	cells and white blood cells in the body.

Sources of Stem Cells

- Stem Cells originate from different parts of the body. Adult stem cells can be found in specific tissues in the human body. Matured cells are specialized to conduct various functions. Generally, these cells can develop the kind of cells found in tissues where they reside.
- Embryonic Stem Cells are derived from 5-day old blastocysts that develop into embryos and are pluripotent. These cells can develop any type of cell and tissue in the body. These cells have the potential to regenerate all the cells and tissues that have been lost because of any kind of injury or disease.

Stem Cells Research in India

- There is no law to regulate the use of stem cells in India. **The Indian Council of Medical Research (ICMR)** has issued guidelines that recognize stem cell therapies only for certain treatments and observes that other types of treatments are unproven and should not be offered as therapy. The Health Ministry has sought to change the rules by amending the law.
- The law that regulates the use and approval of drugs in India is the Drugs and Cosmetics Act.
- At present stem cells are not classified as drugs in India. **If the Drugs and Cosmetics Act is amended by the Government then stem cells will be classified as Drugs and it will come under the jurisdiction of 'Drugs Controller General of India.'** However in

the proposed amendment stem cells that are 'minimally manipulated' are excluded from the definition of a new drug.

- Stem cells are minimally manipulated, meaning they are subjected to minimal manipulation when stem cells are taken from an individual, subjected to minor procedures like rinsing, cleaning, and resizing and do not undergo any other processing steps that may alter their function before being implanted into the same individual.
- India carries out stem cell research. The government of India has been supporting the research through funding agencies like the Department of Biotechnology (DBT), Department of Science and Technology (DST), Indian Council of Medical Research (ICMR). This has resulted in the establishment of the state of the art infrastructure at over 40 premier health research and education institutions.
- **The guidelines are given in the National Guidelines for Stem Cell Research (NASCAR-2013).**

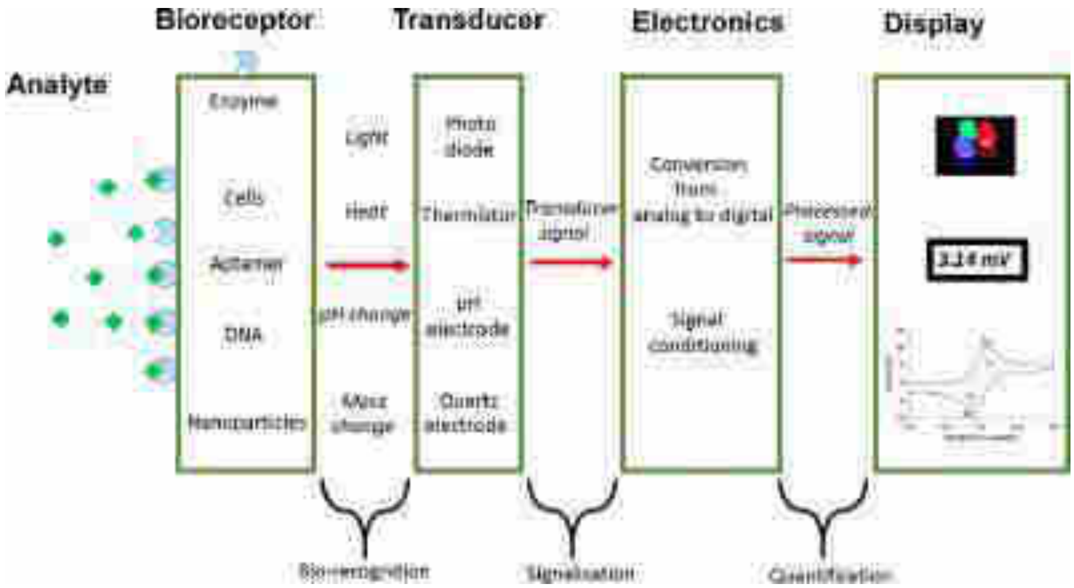
BIOSENSORS

Biosensors are nowadays ubiquitous in biomedical diagnosis as well as a wide range of other areas such as point-of-care monitoring of treatment and disease progression, environmental monitoring, food control, drug discovery, forensics and biomedical research. A wide range of techniques can be used for the development of biosensors. Their coupling with high-affinity biomolecules allows the sensitive and selective detection of a range of analytes.

Characteristics of Biosensors:

A biosensor is a device that measures biological or chemical reactions by generating signals proportional to the concentration of an analyte in the reaction. Biosensors are employed in applications such as disease monitoring, drug discovery, and detection of pollutants, disease-causing microorganisms, and markers that are indicators of disease in bodily fluids (blood, urine, saliva, sweat).

A typical biosensor consists of the following components:



<u>**Fig:1.23 Biosensor**</u>

(Image Source: https://www.ncbi.nlm.nih.gov/)

- **Analyte**: A substance of interest that needs detection. For instance, glucose is an 'analyte' in a biosensor designed to detect glucose.
- **Bioreceptor**: A molecule that specifically recognizes the analyte is known as a bioreceptor. Enzymes, cells, aptamers, deoxyribonucleic acid (DNA), and antibodies are some examples of receptors. The process of signal generation (in the form of light, heat, pH, charge or mass change, etc.) upon the interaction of the bioreceptor with the analyte is termed bio-recognition.
- **Transducer**: The transducer is an element that converts one form of energy into another. In a biosensor, the role of the transducer is to convert the bio-recognition event into a measurable signal. This process of energy conversion is known as signalization. Most transducers produce either optical or electrical signals that are usually proportional to the amount of analyte–bioreceptor interactions.

- **Electronics**: This is the part of a biosensor that processes the transducer signal and prepares it for display. It consists of complex electronic circuitry that performs signal conditioning such as amplification and conversion of signals from analog into the digital form. The processed signals are then quantified by the display unit of the biosensor.
- **Display**: The display consists of a user interpretation system such as the liquid crystal display of a computer or a direct printer that generates numbers or curves understandable by the user. This part often consists of a combination of hardware and software that generates results of the biosensor in a user-friendly manner. The output signal on display can be numeric, graphic, tabular, or an image, depending on the requirements of the end-user.

Applications of Biosensors

<u>Fig1.24 Applications of Biosensors</u>

(Image source: https://www.ncbi.nlm.nih.gov/)

BIOGRIDS

BioGRID stands for Biological General Repository for Interaction Datasets. It is an open-access database for the purpose of curation and archival storage of genetic, protein and chemical interactions related to all major model organism species and humans. The Biological General Repository for Interaction Datasets (BioGRID) was created in 2003, originally called the General

Repository for Interaction Datasets (GRID, by Mike Tyers, Bobby-Joe Breitkreutz, and Chris Stark at the Lunenfeld-Tanenbaum Research Institute at Mount Sinai Hospital.

It strives to provide a comprehensive curated resource for all major model organism species while attempting to remove redundancy to create a single mapping of data. Users of The BioGRID can search for their protein or publication of interest and retrieve annotation, as well as curated data as reported, by the primary literature and compiled by in house large-scale curation efforts. The BioGRID is hosted in Toronto, Ontario, Canada and Dallas, Texas, United States and is partnered with the Saccharomyces Genome Database. The BioGRID is funded by the BBSRC, NIH, and CIHR. BioGRID is a member of the International Molecular Exchange Consortium (IMEx).

CHAPTER 2: INFORMATION COMMUNICATION TECHNOLOGY

2.1 INTRODUCTION

Information and Communication Technology (ICT) generally refers to the role of integrated communications,telecommunications, computers and computing devices, necessary enterprise software, storage devices, middleware, and the audiovisual systems which facilitate its users to store, transmit, manipulate and access information**, i.e. ICT is the convergence of telephone networks and audio visual systems with computer networks through a single cable network etc.** The word Information Technology was officially coined by **Jim Domsic** of Michigan in November 1981.

Fig 2.1: information communication Technology

(Image source: searchcio.techtarget.com)

Broadly it can be defined as follows

INFORMATION	COMMUNICATION	TECHNOLOGY
knowledge obtained from reading, studying or research and investigation etc. In other words, information is a knowledge which is used for fulfilling our tasks. For example, warning the public about any forthcoming disaster requires transmission of information. Radio, television, internet, cable network, etc., are the tools which facilitate the transmission of information.	It is a transmission of information and messages between individuals, groups or any entity through the use of mutually understandable symbols, science and semiotic rules. In other words, it is the exchange of information by verbal, written or any other medium such as telephone lines or computers etc. In the 21st century the new forms of communication such as the internet, email or video conferencing etc. are becoming more popular.	It is a transmission of information and messages between individuals, groups or any entity through the use of mutually understandable symbols, science and semiotic rules. In other words, it is the exchange of information by verbal, written or any other medium such as telephone linesor computers etc. In the 21st century the new forms of communication such as the internet, email or video conferencing etc. are becoming more popular. The scientific knowledge, techniques, skills, methods, and processes are used for creating products and processes for fulfilling human needs. Technology is one of the basic requirements for communication through ICT.

		Fax machines, telephone and cable networks, etc., are the devices used for extending communication. Satellites, radio, cable networks and the World Wide Web (www) are powerful tools for spreading information.

Humans have been storing, retrieving, manipulating, and communicating information since the Sumerians in Mesopotamia developed writing in about 3000 BC,but general use of the term information communication technology in its **modern sense** had **appeared first** in an article published in the Harvard Business Review; where the authors **Harold J. Leavitt and Thomas L. Whisler** write about it as "the new technology does not yet have a single established name. We shall call it information technology (IT)."
The definition which was given by them consists of three categories: techniques for processing, the application of statistical and mathematical methods to decision-making, and the simulation of higher-order thinking through computer programs.

Note:- Based on the storage and processing technologies employed, it is possible to distinguish four distinct phases of IT development: pre-mechanical (3000 BC – 1450 AD), mechanical (1450–1840), electromechanical (1840–1940), and electronic (1940–present)

It was with the beginning of the era of computers that the field of Information Technology gained prominence throughout the world.

EVOLUTION OF COMPUTING TECHNOLOGY AND DEVICES

Since the period of 1940's five generations of computers have come into existence which can be categorised into:-

GENERATION	CHARACTERISTICS
First generation computers (1946-1959)	In 1946, the first successful electronic computer ENIAC (Electronic Numeric Integrator and Calculator) was developed by Presper Eckert and William Mauchly.The First generation computers used vacuum tubes for circuitry and magnetic drums for memory. The computers in this generation relied on 'machine language' which was the basic programming language. **Examples include** ENIAC, EDVAC, UNIVAC, Z3 and IBM etc.
Second generation computers (1956-1963)	In these computers vacuum tubes gave way to transistors. They were superior to vacuum tubes and were faster, small , cheap using less electricity. **Examples:- IBM 1401, IBM 1620, MCR 300, RCA 301 etc.**
Third generation computers (1964-1971):	In this phase integrated circuits were developed and transistors were miniaturized and integrated on the silicon chips. This increased the speed and efficiency of computing and enabled machines to run several applications at once.
Fourth generation computers (1971- Present):	The advent of microprocessors brought the era of the fourth generation of computers In 1971, Intel inc. developed the first microprocessor called Intel 4004 by positioning all computer components in a single chip.
Fifth Generation computers (future endeavours)	5th generation computers are based on artificial intelligence which is still in development. Some of the technologies which are emerging include voice recognition systems etc.

CONSTITUENTS OF INFORMATION COMMUNICATION TECHNOLOGY (ICT)

The several components of Information Technology could be grouped as follows:

1.Computer Technology: Computer technology has led to immense growth and expansion in the information transformation process and the recent developments in computer and communication technologies have enabled smooth management of information data, several institutions and organizations, and work processes.

2. Communication Technology: The fast growth in Communication Technology has created a revolution in the Information Communication Technology sector. Modern technology like silicon chip internet, fibrosis optics, telephone, television, etc., are some of the essential components of the communication network.

3.Optical communication systems: optical communications are used in long-distance digital networks which have revolutionized the telecommunication sector. Light is used as the career of information and optical fibers act as the medium of transmitting these light signals.

4. Satellite communication systems: The system of satellite communication has become one of the most popular and extensively used technologies in the ICT sector. In today's scenario, this system has enabled transmission of information even in difficult geographical areas such as mountains, rugged topographical Zones, and unreached regions of the world, etc.

UTILITIES OF INFORMATION COMMUNICATION TECHNOLOGY

- **Speedier communication:** Earlier the transmission of messages and news took a long time to reach its destination. However, with the advent of the internet and other ICT options, communication comparatively became much faster and more efficient. Messages sent via emails, messaging apps such as WhatsApp, Telegram, etc became faster and at an instant.
- **Lower cost of communication**: use of the internet became more cost-effective than the traditional modes of communication such as postal service, courier service, or traditional telephones. Large amounts of data can be accessed at the very low-cost due reduction in

the cost of internet services due to the development of ICT technologies such as 4G internet services etc.

- **Reliability in communication**: The growth of the Internet and other IT services has emerged as one of the most reliable modes of communication because the information could be accessed and retrieved any time from anywhere. With the advent of new modes of communication such as video conferencing, email, databases, it has become easier to perform different business transactions.
- **Data storage efficiency and file management**: The advent of ICT services such as cloud hosting, cloud computing, etc., resulted in better data storage, file management. Today the storing of backup business data has become much more efficient and easy.

It has also reduced the amount of paperwork required for any work and has made transfer and access of data to remote locations more efficient.

- **Efficiency and Productivity:** ICT has made the sharing of information much more efficient and effective for all people around the world. People can share news and information, exchange opinions through ICT services such as the Internet, online forums, discussion groups on WhatsApp, Telegram, etc. All these developments are contributing to the development of a knowledge-based society.
- **Paperless environment**: The advancement and progress of ICT led to the growth of a paperless environment in which information can be stored and retrieved digitally instead of paper. The use of emails, online chat, and instant messaging services for communication is contributing to the development of a paperless environment.
- **Innovation and research:** ICT services are assisting in various research and innovation activities. The use of IT services has been widely credited in the field of innovation and research such as space technology, robotics, artificial intelligence, etc.
- **Entertainment and Recreation industry**: The growth of ICT has improved the options of entertainment for people all over the world. New modes of entertainment have emerged such as cable television, online video streaming, online games, and other over the top Platforms like Amazon, Netflix, etc.
- **Improved social connectivity**: ICT services have led to the emergence of various social networking websites such as Facebook, Twitter, and various social networking applications such as WhatsApp, Telegram, Instagram, etc. All these have led to an

improvement of social interactions and inter-relationships among the members of society and now it is easier to connect with our friends and relatives through these social networking websites and apps.

- **ICT Transcends Boundaries**: The speed and faster means of communication through the internet have resulted in rapid information retrieval, accessibility and versatility. All these have created borderless sources for services, information, and communication, and are contributing to the emergence of a borderless world.

2.2 NEGATIVE IMPACT OF INFORMATION COMMUNICATION TECHNOLOGY

- **Social problems**: Today's scenario is such that online communication is getting priority over real-time conversations. People are becoming more individualistic and isolated, which is creating social problems in society like lack of social engagements, which results in alienation and disenchantment with Society. Several Social crimes have also been occurring over the Information Communication Technology Platforms.
- **Issues related to Health**: Extended exposures to computers causes negative impacts on health. Individuals who use information technology devices suffer from bad posture, eye strain, physical and mental stress, etc. To deal with these issues an ergonomic environment can be created such as an ergonomic chair for reducing back strain, and screen filter for reducing eye strain.
- **Expensive Technology**: ICT is relatively expensive technology and firms operating on a small scale are unable to afford this expensive technology which puts them at a disadvantage. Even The digital India mission of Government Of India is pegged to have a huge implementation cost.

With the exponential growth of information communication technology and rise of several emerging fields like- **automation, artificial intelligence**, and **digitization** of work process among others, certain new concerns have arisen related to:

- **Cyber Security: Growth of Cybercrimes like hacking, phishing, crimes against women, etc**
- **Privacy concerns: The risk is due to the Personal Information of users being** connected through cookies, electronic profile, and spyware, etc. Cookies are used for identifying users by webcasting, e-commerce, and web applications. The electronic

profile includes personal details such as age, address, marital status, etc., which are preserved in a database and can be sold to the interested parties. Spyware collects user information without users' knowledge by sneaking in like a computer virus.

- **Loss of Employment: There are concerns related to job losses as ICT Technology has substituted many positions that were occupied by humans. Like the use of Robots in few places to replace manpower.**

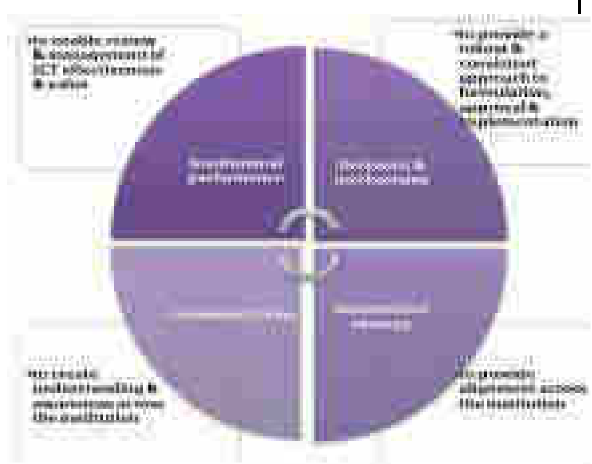
APPLICATIONS OF INFORMATION COMMUNICATION TECHNOLOGY (ICT)

<table>
<tr><th>INDUSTRY</th><th>EDUCATION</th></tr>
<tr><td>ICT has contributed in the industrial sector right from production, planning, control systems, supply chain and management etc. Buying and selling of bonds in the stock markets have been made possible only due to the contribution of the ICT sector. Research and development activities utilise the latest computer technologies and the information available from different sources such as the internet etc.

</td><td>ICT has enabled students, teachers and researchers to gain knowledge with the help of computers and the internet. The Internet, digital libraries and electronic sources of information are becoming more popular among students all over the world. ICT has opened new opportunities in the education sector such as Massive Open Online Courses (MOOCs) etc.

</td></tr>
<tr><th>BUSINESS AND COMMERCE</th><th>MEDICINE</th></tr>
</table>

Computers are used for managing the financial and business records, databases of workers and employees etc. Digital Technologies, sophisticated hardware, software and communication technologies are extensively used in day to day commerce and business transactions. Online buying and selling of products and services through **E-Commerce** platforms have been made possible by the use of Information and Communication Technologies. Computers, internet, software and telecommunication technologies are utilised for connecting the customers and suppliers for carrying out e-commerce transactions.  	ICT in the field of medicine has immense possibilities. For example, MRI, in which the computer combines the pictures and produces 3D images of bodies organs. New Emerging Technologies such as robotic surgeries performed by specialists from remote locations utilise Information and Communication Technologies. 
ENTERTAINMENT	**GOVERNANCE PROCESSES**

Various entertainment options such as online games, streaming music, digital television broadcast, satellite radio, etc have been made possible with the help of internet connections via computers, mobile phones, cable connections or through Wi-Fi, 4G technologies etc.	Information and Communication Technologies have made governance easier, smoother, and citizen centric. **Administration :-** The provision of e-government services such as online post matric scholarships, online filing of income tax returns etc., have been made possible through the application of Information and Communication Technologies. **Banking:** ICT has become the center of the banking system. The rise of electronic banking services which includes services such as electronic fund transfer, automated teller machine (ATM), internet banking, Unified Payment Interface (UPI) etc., have been made possible due to the contribution of the ICT sector. 

CONCLUSION

The rise of Information Communication Technology (ICT) has changed the world like never before. It has enhanced the human ability to communicate more efficiently and easily and changed the lives of individuals, groups, and entities around the World. The challenges and concerns arising out of ICT needs to be tackled properly in order to ensure its benefits reach all and become inclusive as well as the losses incurred are greatly reduced. In order to achieve this goal the contribution of all the stakeholders including the service providers, users, civil society and the government is necessary. If used to an effective level with proper integration along the mainstream developmental paradigms.

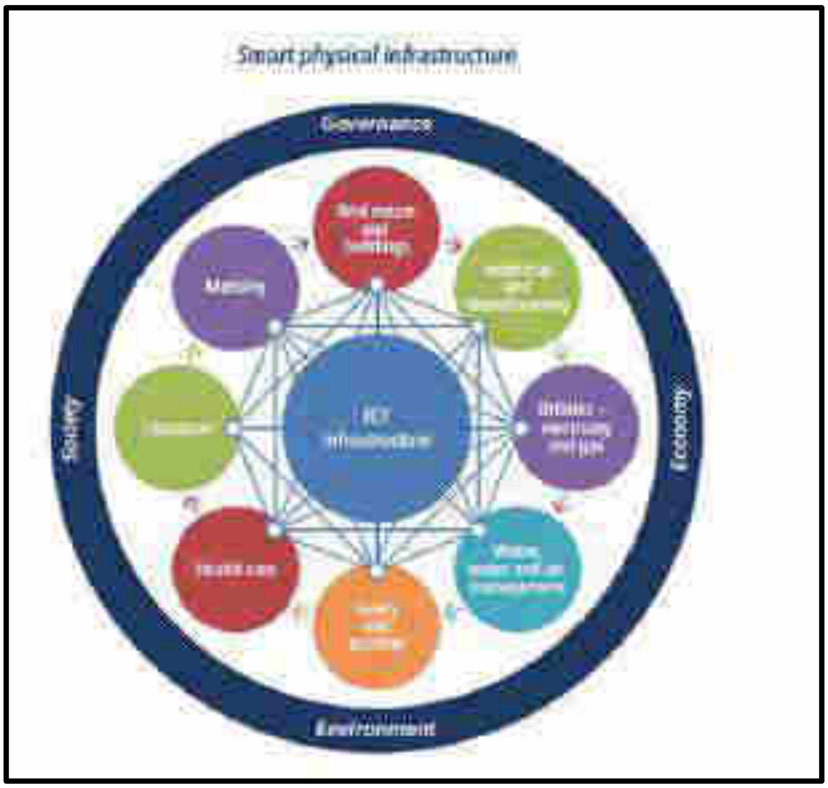


Fig 2.2: Future of IT

(image source:ITU NEWS MAGAZINE)

2.3 TELECOMMUNICATIONS

INTRODUCTION

Telecommunications,or telecom, refers to exchange of information over significant distances by electronic means and several types of voice, data and video transmission are also included in It.

On a broader level the term includes a number of information transmitting technologies such as telephones (wired and wireless), microwave communications, fiber optics, satellites, radio and television broadcasting, the internet and telegraphs.

Fig 2.3: Telecommunications Process

There are several types of telecommunications networks, it is quite known that the simplest type of telecommunications takes place between two stations, but it is common for multiple transmitting and receiving stations in order to exchange data between them. Such an arrangement is known as telecommunications network. One of the biggest examples of telecommunications networks is growth 9f internet services. On a smaller scale, some of the examples include:

- Telephone networks
- Corporate and academic wide-area networks (WANs)
- Cellular networks
- Police and fire communications systems
- Groups of amateur (ham) radio operators
- Taxi dispatch networks
- Broadcasting networks

The rise and initial growth of basic telecommunications technology started with **Evolution of Mobile Networks** which had revolutionized the telecommunication systems all over the world.

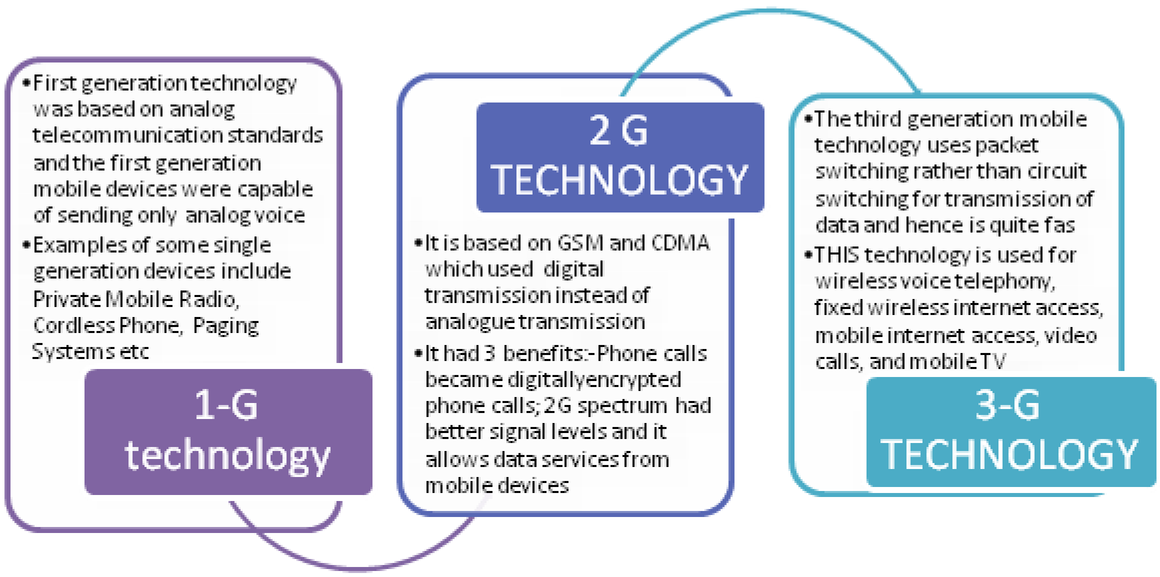
MOBILE(CELLULAR) GENERATION

The term mobile generations is generally associated with the change in the nature of **Mobile Networks communication speed**, technology, data capacity, frequency, latency etc. With the evolution and growth of each generation there were some new techniques, new features, and higher capacities which were added to the previous generation of Mobile technology.

The terms usually used for the evolution of mobile communication technologies have been designated as 1G, 2G, 3G, 4G, and 5G.

1- G, 2-G and 3-G TECHNOLOGY

Before the advent of Single generation technology (1G), the term 0G was used which referred to **the pre-cell phone mobile technology based on mobile radio telephones**.These systems or technologies were called pre-cellular technology which were mounted on cars and trucks.these systems came to be known as **zero generation systems.**



FOURTH GENERATION (4G) TECHNOLOGY

In addition to voice and other services of 3G, the 4th generation mobile technology provides wireless mobile broadband internet.Its various applications include improved web access, IP telephony, video conferencing, cloud computing, gaming services high-definition mobile TV etc.It is to be noted that the data transmission speed provided by 4G technology is up to tenfold of existing 3G mobile networks. 4th Generation technologies eliminate circuit switching which was used in 3G networks while offering Voice over Internet protocol and downloading speeds up to 100mbps and even higher.

FIFTH GENERATION(5G) MOBILE TECHNOLOGY

- 5th generation mobile technology denotes futuristic phase of mobile telecommunication beyond the fourth generation standards which is currently under development.
- Some of the features of 5G technology consists of higher data speeds, lower battery consumption, better coverage, lower traffic fees etc. The broadcasting data speed of 5G networks would be in Gbps.
- 5G Technology is expected to significantly reduce the latency compared to LTE.
- 5th generation mobile technology is expected to provide several simultaneous connections.
- It is expected to be rolled out in 2020 as per the current development.
- 5G technology will facilitate meeting the needs of new evolutions of technology such as the Internet of things etc.
- World Wide Wireless Web (WWWW) and the Cognitive Radio Technology are some.of the other concepts associated with 5G technology.

Fig 2.4: 5G TECHNOLOGY

(Image source: qualcomm)

Challenges With 5-G Technology

There are several limitations associated with 5G Technology that have invoked concerns in policy circles across the world in general and India In particular.

It is difficult to attain the stipulated speed of 5G, considering the inadequate technological support in most parts of the world. While there will be challenges replacing the old devices that do not support 5G.

Issues of speed and latency particularly in India where Average downloading speed is around 9 Mbps compared to a global average of 23 Mbps.

Large numbers of users in India pose significant challenges for increasing the consumer base to meet the demand-supply gap.

The switching to 5G will be infrastructure intensive and developing 5G ready infrastructure is very expensive.

Apart from all these challenges, there has been a recent controversy surrounding the safety and security concerns related to the Huawei Company.

The reason related to Huawei's origin, because the company was owned by Ren Zhengfei, formerly an engineer in the People's Liberation Army of China. His connections to the military and the Communist Party, alongside those of senior Huawei executives, have been cited as a security concern for foreign customers. The US has banned Huawei, citing that the company is funded by Chinese state security. Also, India's Department Of Telecom has flagged concerns over possible bugs in the equipment sold by a Chinese company. Indian Security agencies have also raised fears over the possible presence of embedded spyware or malicious software ('malware') that could allegedly be used by the Chinese intelligence to snoop into conversations and data flowing through the Indian network or even shut down communications in Delhi and Mumbai sitting in Beijing.

However, India recently rolled out the 5G trials in which it permitted the participation of Huawei. But the recent developments on the Strategic and military front where tensions are simmering between India and China may force a possible relook at the approved trials, as India has blocked 59 Chinese apps such as TikTok and WeChat, claiming they are a threat to national security.

Moreover, recently USA has pushed its allies to bar Huawei, a Chinese telecom giant, from building next-generation 5G mobile networks, claiming its equipment can be used to spy for Beijing. It has also made Britain to cut the firm out of the most sensitive "core" elements of 5G that access personal data. After this, India is also reconsidering the country's 5G rollout plans and whether Huawei should be allowed to participate.

2.4 SOME CONCEPTS RELATED TO INFORMATION COMMUNICATION TECHNOLOGY

Voice over internet protocol (VOIP):

It is an internet-enabled technology WHICH FACILITATES voice calling over the internet. In this protocol Broadband connectivity is used for making calls with computers, smartphones, etc. some of the examples of this version are. Skype, Yahoo Messenger, MSN Messenger, etc., which provide VOIP services.

Internet Protocol Version 6(IPV 6):

Internet Protocol Version 6 (IPv6) is a network layer protocol that allows communication and data transfers to take place over the network.

Features of IPV 6.0:

- IPv6 came into existence in 1998 intending to replace IPv4.
- It is a 128 bit IP address
- It is an alphanumeric addressing method.
- IPSec (Internet Protocol Security) is built into the IPv6 protocol

- It Allows storing an unlimited number of IP addresses.
- Unicast, multicast, and anycast are types of addresses.

IPv6 was developed to solve the address space exhaustion in IPv4. IPv4 uses a 32-bit address scheme which allows it to store more than 4 billion addresses. IPv6 uses a 128-bit address scheme which allows 340 undecillion unique address space.

WI-FI TECHNOLOGY

Wi-Fi is a wireless network technology that provides wireless high-speed Data Services and network connections using radio waves.

This technology is based on IEEE 802.11 standards for connecting devices. Wi-Fi can connect devices such as personal computers, video game consoles, smartphones, smart digital headphones, etc., to the internet via a wireless network access point.

WiFi is a new characteristic of networking and has fetched a new feature in the field of networking. The data broadcasting which is finished using radio waves allows users to get easy access to the internet for objective sharing all around the world.

For example, Now it is easier to establish a computer network in any type of business like companies, coffee shops, Libraries, campus, Hotels, colleges, universities, private institutes, etc. Wi-Fi Technology enables us to get more profit from business and facilitates connecting to the client anywhere or at any time.

Some of the peculiar features of Wi-Fi include: it has more Scalability and efficient performance as compared to other technologies. It has more extensive reach than conventional networking technology and has great power for consumption as compared to other networks. Moreover, WiFi provides more reliability due to its security system which protects your data, and also there is no need for cabling in Wi-Fi Technology.

Wi-Fi Calling- Wi-Fi Calling is a service for smartphones which, just as it sounds, allows you to call over a Wi-Fi network. Wi-Fi calling relies on a technology called SIP/IMS that tunnels your call through the internet, instead of a cell tower. Consequently, you’re not using the cell tower to place the call, which means that you don’t need cellular service. When placing a WiFi call it’s just like placing a regular call, without logging in or using an app. Your carrier and phone will determine if you can call through WiFi or not.

Recent Development

The Government of India has given its go-ahead for Wi-Fi services in flights. Passengers will be now allowed to use Wi-Fi during flights in the Indian airspace as the government has issued a notification in this regard. The government notification says that subject to permission by the main captain, all flights will be able to switch on in-flight Wi-Fi for the benefit of fliers.

But the availability of the Wi-Fi during flights will be -- broadly -- subjected to two conditions:

- The main captain will have the authority to switch on or switch off the Wi-Fi in flights, and the captain will be required to follow certain guidelines on this matter. For example, Wi-Fi would be switched on only when the plane is at the cruising speed. During take-off or landing, it will not be available. Also, if the weather is not clear, chances are that the captain will not turn on Wi-Fi.
- Each plane that offers in-flight Wi-Fi will have to be certified by DGCA for this purpose before fliers in it can enjoy connectivity.

The official notice by the Civil Aviation Ministry states: The pilot-in-command may permit the access of internet services by passengers on board an aircraft through Wi-Fi onboard when a laptop, smartphone, tablet, smartwatch, e-reader or a point of sale device is used in flight mode or airplane mode. Provided that the director-general shall certify the aircraft for the usage of internet in-flight through Wi-Fi onboard subject to procedures as specified in this behalf.

The notice further states that an aircraft shall be deemed to be in flight when all its external doors are closed, following embarkation until the moment when any such door is opened for disembarkation.

The latest notification also states that the use of mobile phones may be permitted by the pilot-in-command after the aircraft has landed and cleared the active runway, except when the landing takes place in low visibility conditions as may be determined by the director-general.

Long Term Evolution (LTE)

Long term evolution is a standard for wireless broadband technology offering reduced latency, incremental data speed, bandwidth capacity that can be Scalable with the present GSM, and UMTS Technology in use.

WiMAX technology

WiMAX Technology: Worldwide Interoperability for Microwave Access (WiMAX) is a wireless technology for providing Point to multipoint (PMP) wireless broadband internet access. It can provide wireless broadband access up to 10 miles for the mobile stations and around 30 miles for fixed stations... It can provide data services at speeds up to 72 Mbps.

LI-FI(Light Fidelity) TECHNOLOGY

LiFi(Light Fidelity) is a high-speed wireless communication technology that uses visible light to transmit information. It has some similarities to existing Wi-Fi technology, as well as some huge differences.

Wi-Fi and LiFi are similar because both technologies are wireless, but also very different because unlike Wi-Fi, which relies on radio waves, LiFi uses visible light communication (VLC) or infrared and near-UV spectrum waves.

In other words, LiFi works by using visible light, like the light that is emitted by any regular lamp or bulb.

How does LI-FI work?

- Light Fidelity is a Visible Light Communications (VLC) system and can accommodate photo-detectors for receiving light signals and uses a signal processing element to convert the data into streamable content.
- It runs on visible light instead of radio waves used in Wi-Fi.
- In LiFi technology the data is fed into an LED light bulb (with signal processing technology), after which data is sent at rapid speeds to the photo-detector (photodiode).
- The tiny changes in the rapid dimming of LED bulbs are then converted by the ‘receiver’ into electrical signals.

- The signal is then converted back into a binary data stream that the user would recognize as web, video, and audio applications that run on internet-enabled devices.

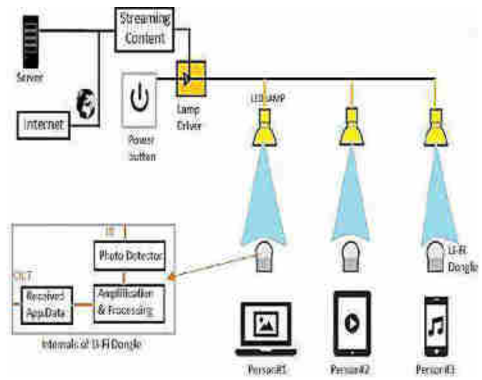


Fig 2.5: Working Of Li-Fi Technology

(Image source: scienceabc.com)

Advantages of Li-Fi:

Issues Related To Light Fidelity Technology:

Li Fi uses visible light to transmit data but in case of Darkness or lack of visibility it may not be very useful.	If you have a WiFI router installed in one room of your house, you can connect your devices sitting anywhere in the house, but this is not the case with LiFi
There are issues of reliability in this technology (due to it being dependent on visible light) and has high installation charges.	The use of lifi Technology can disrupted by physical obstacle in its way since visible light cannot pass through Opaque objects does a user has to be close to internet source in case there is any hindrance in between

UTILITIES OF Li-Fi Technology:

Fig 2.6: LI-FI Technology Applications

(Image source: Gulf news)

- It can be used in street and traffic lights. In order to communicate with the vehicles and with each other the traffic lights would be useful.
- LiFi can be used for real time traffic control and each traffic and street light post can be converted into access points to convert roadsides into wireless hotspots.

- Accidents can be prevented as vehicles with LED headlights may be able to communicate with each other or exchange real time information.
- LiFi can be used in aircraft, where most for control communication in place of current radio waves.
- It will also have applications in military and navigational operations, as it can work underwater.
- In future it may open opportunities for wireless transmission of power, wherein the smartphone will not only receive data through Li-Fi, but will also receive power to charge itself.

LIGHT EMITTING DIODE (LED)

- A light releasing diode is an electric component that emits light when the electric current flows through it.
- It is a light source based on semiconductors.
- When current passes through the LED, the electrons recombine with holes emitting light in the process.
- It is a specific type of diode having similar characteristics as the p-n junction diode.
- Which means that an LED allows the flow of current in its forward direction while it blocks the flow in the reverse direction.
- Light-emitting diodes are built using a weak layer of heavily doped semiconductor material.
- Based on the semiconductor material used and the amount of doping, an LED will emit a coloured light at a particular spectral wavelength when forward biased.

Applications Of Light Emitting Diode (LED):

TV Backlighting	A TV's backlight is the major power consuming source. Uses of LEDs can give an efficient power reduction. In the edges of TV, using an LED will be a cost reduction choice. Using LEDs directly behind the display provides better contrast. LEDs has been replacing CFLs and LCDs when it comes to TV backlighting

Smartphone Backlighting	With the use of LED, the backlight design of the smartphone can be thinner and be made within low cost. The price of LED may vary according to the size of the smartphone display. Due to the lower output voltage, they ensure longer battery life
Displays	LEDs display boards are common now these days and are used outdoors like storage signs, billboards, road signs etc. In sign boards which has multiple languages conveying signals, use of more LEDs will be beneficial in terms of less power consumption
Automotives	The Use of LEDs in the automotive industry is growing. With LEDs, energy is saved and there is a clearer visibility. These are extensively used in the back and rear of an automobile for better accessibility. LED lighting can improve safety of pedestrians and drivers as it enhances visibility when it is ON, OFF and dimmed in any part of the journey.
Dimming of Lights	Few LED applications include dimming of lights which helps in reducing energy consumption: ● This dimming feature is also used in Appliances where it is of two types. ● Global Dimming where all LEDs are dimmed together. ● Local Dimming where LEDs are dimmed indepently.

LEDs vs LCDs (differences):

LCD	LEDs
LCD production uses mercury thus harm environment	LEDs use no mercury thus environment friendly.
All LCDs are not a subset of LED TV's	All LEDs are a subset of LCD TV's.
LCDs primarily use fluorescent lights	LEDs use light emitting diodes

Fluorescent lights used are usually placed behind the screen.	Light emitting diodes are usually placed behind the screen or around the edges.
LCDs are usually thicker in size and lack energy efficiency compared to LEDs	LEDs are much thinner in size and are much more energy efficient.

ORGANIC LIGHT EMITTING DIODE(OLED)

OLED is a Light emitting diode (LED) in which the emissive electroluminescent layer is a film made of organic material containing carbon like wood, plastic, polymers etc which emits light on the flow of electric current.The organic layer is placed between two electrodes - a transparent anode and a metallic cathode.

OLED is capable of producing light of different colours and they do not require a backlight and directly produce a correct colour which also saves power and space.In low light conditions, OLED displays provide a higher contrast ratio compared to the LCD displays.

OLED displays are considered better than the existing display technologies due to their fast response time, better contrast levels, wide viewing angles, and perfect brightness.

OLEDs are used for creating digital displays on television screens, smartphones, computer monitors, handheld game consoles, and personal digital assistants.

An OLED display can be based on the passive matrix (PMOLED) or active matrix (AMOLED) control schemes. In PMOLED, each row in the display is controlled sequentially one by one. In the AMOLED scheme, a thin film transistor backplane is used for directly accessing and switching each individual pixel on or off. This provides higher resolution and larger display sizes.

Advantages Of OLED Technology:

Better picture quality	Environment Friendly	Thinner and have better

		Power Efficiency
Response time is fast and rapid	Strong durable and break resistant	Future production costs may be Scalable

Disadvantages of OLED Technology:

Lower lifetime due to limited lifetime of organic materials	Water and other liquid materials may cause damage
Poor readability and visibility in outdoors or bright light	Power consumption in OLED displays is uneven.

LIGHT DETECTION AND RANGING (LiDAR):

LiDAR, or light detection and ranging, is a popular remote sensing method used for measuring the exact distance of an object on the earth's surface. LiDAR didn't get the popularity it deserved, Even though it was first used in the 1960s when laser scanners were mounted to airplanes. However, after the introduction of GPS, in the 1980s it became a popular method for calculating accurate geospatial measurements.

LiDAR uses a pulsed laser to calculate an object's variable distances from the earth's surface. These light pulses — put together with the information collected by the airborne system — generate accurate 3D information about the earth's surface and the target object.

There are three primary components of a LiDAR:- the scanner, laser, and GPS receiver. Other elements that play a vital role in the data collection and analysis are photodetector and optics. Most government and private organizations use helicopters, drones, and airplanes for acquiring LiDAR data

LiDAR systems are divided into two types based on their functionality:

- **Airborne LiDAR-**Airborne LiDAR is installed on a helicopter or drone for collecting data. As soon as it's activated, Airborne LiDAR emits light towards the ground surface, which returns to the sensor immediately after hitting the object, giving an exact measurement of its distance. Airborne LiDAR is further divided into two types — Topological LiDAR and Bathymetric LiDAR.

- **Terrestrial LiDAR- these systems are mounted on moving vehicles or tripods on the earth surface for collecting accurate data points and are quite common in observation and monitoring of highways, analyzing infrastructure, or even collecting point clouds from the inside and outside of buildings. Mobile LiDAR and Static LiDAR are two types of terrestrial LIDAR systems.**

ISSUES WITH LiDAR:-

- It can measure the distance of objects up to 5 meters away but won't farm well for objects in the vicinity
- It fails to detect glass wall or door
- It also cannot function well in snow, fog, dust or rain

2.5 EMERGING TECHNOLOGIES IN FIELD OF INFORMATION TECHNOLOGY

INTERNET OF THINGS(IoT):

IoT is the interlinking of digital devices, people, machines, appliances, and other objects with one another through wireless networks.

It allows machines and people to be connected and communicate as well.

It is considered the future of the internet. This version of the internet is about data that is created by things.

Internet of Things Explained:

1. Any device that can be connected will be connected.
2. Any device that can be switched on and off will be connected.
3. Most of the connected devices will have an Internet Protocol (IP) address. With IPv6, billions of devices can be connected with ease.
4. Things can be connected with IoT:

- Connected Homes: interlinking of household appliances to the network.
- Connected Wearables: smartphones, smartwatches, fitness bands, etc.
- Connected Cars: vehicles connected to the network.
- Connected Cities: smart meters that can analyze the usage of gas, water, electricity, etc.; connected traffic signals; smart bins, etc.
- Different networks would be connected, like as mentioned below:
    - BAN (Body Area Network) – Wearables
    - LAN (Local Area Network) – Smart Homes
    - WAN (Wide Area Network) – Connected Cars
    - VWAN (Very Wide Area Network) – Smart City
        -

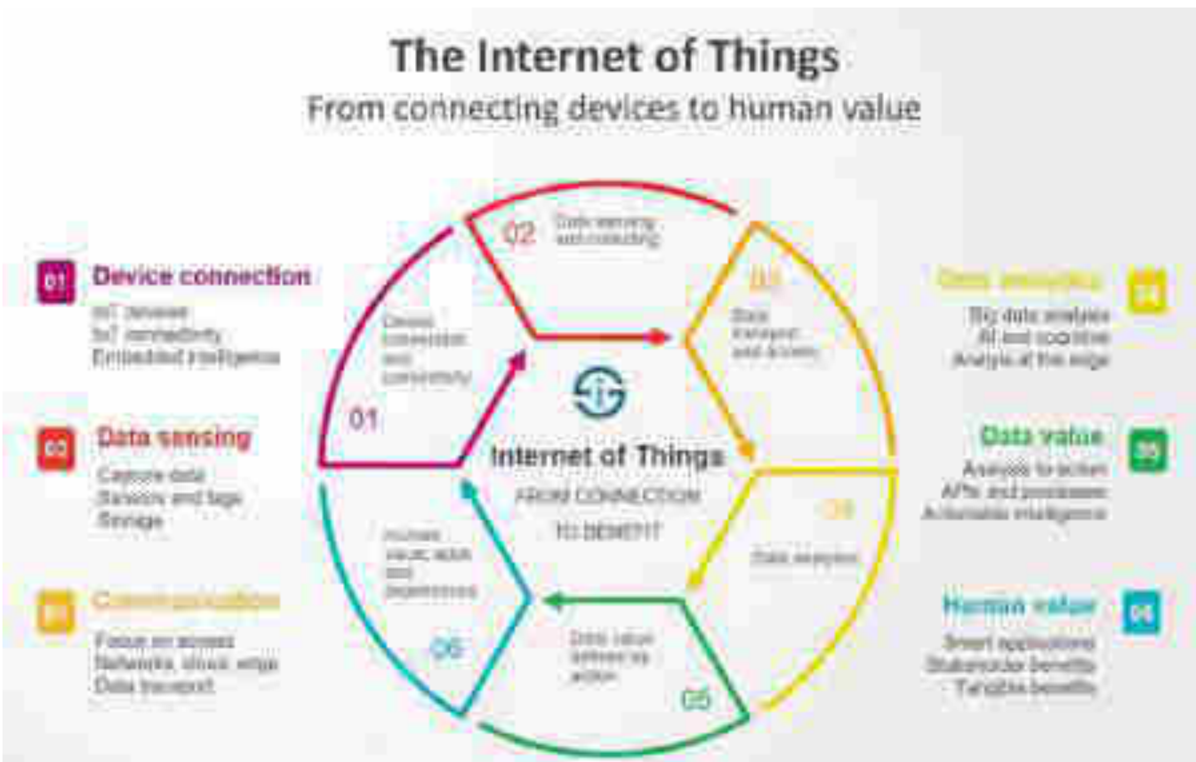


Fig 2.7: Internet of Things

(Image source: Pib)

APPLICATIONS OF INTERNET OF THINGS:

Daily life: IoT can be	**Agriculture**: IoT can	**Transportation**: IoT	**Smart Cities**: IoT

used to do small tasks in daily life such as coffee-making as soon as the owner of the house returns home, refrigerator indicating that vegetables need to be bought and/or ordering them automatically from the e-store, etc. It can also be used in offices.	be used to improve overall productivity through better weather forecasting, soil nutrient content, pest infestation, etc	can be used on toll booths, traffic management, driverless cars, etc. It can also be used in fleet management, safety assistance, improved logistics, etc.	can be used to make cities better places to live. It can be applied in solid waste management, smart power grids, smart energy management systems, etc
Industry: IoT can be used to reduce human error, increase efficiency, and improve productivity, etc.	**Healthcare**: there are several benefits in the medical industry. Better diagnosis of diseases, wearable monitors of vitals, sophisticated connected equipment, etc	\ **Media/Advertising**: Companies can use IoT to analyse and predict consumer behavior and apply target marketing for better ROI in advertising/marketing campaigns, etc. Big data and data mining concepts can be used in this regard.	**Government policies and services**: the government can use IoT to offer better citizen services.

SCENARIO IN INDIA:

The Government of India envisages to use Internet of Things (IoT) as part of the Digital India Mission.The National Digital Communications Policy was launched in 2018 to develop and apply IoT, 5G technology, machine to machine (M2M) communication, etc.

The government also permitted 100% FDI in the telecom sector. This should also aid the development of IoT in India.The Department of Electronics and Information Technology (DeiTY) also published a draft policy for IoT in India.

The government has set a target of USD 15 billion for the IoT market by the year 2020. This would be 5 – 6 % of the global Internet of Things (IoT) industry.

ISSUES AND CONCERNS RELATED TO INTERNET OF THINGS:

- Loss of jobs because of the replacement of humans with machines.
- There is the issue of misusing personal data without consent of the owning party by internet/social media companies thus privacy and safety issues are there..
- Digital surveillance also poses challenges like there are concerns that smart homes are susceptible to privacy invasions.
- Risks of financial frauds and hacking of banking and financial details of people or state authorities. By non state individuals or cyber hackers.

Fig 2.8: IoT Developers Survey

(*Image source: Secureworld)*

There is a need to have better regulation and policy frameworks for regulating and monitoring Internet of Things applications. Firewalls and safety software should be improved and data confidentiality should be priority for all stakeholders.

2.6 FOURTH INDUSTRIAL REVOLUTION AND INFORMATION TECHNOLOGY

INTRODUCTION:

Human history has been one big roller coaster ride. First, we discovered fire, then agriculture, wheels, then factories and trading which were followed by steam power, electricity and mass production.Then came the age of computers, the internet, gene-editing, block chain, self-driving cars, and artificial intelligence, to neuro-technological brain enhancements.

The evidence of dramatic change is all around us and it is occurring at an exponential speed.

The industrial revolution was one of the most significant game-changing periods of human history. Also termed as the industrial age, it was a period of immense technological, socio-economic and cultural changes.This period introduced mass production and replaced hand tools with machines.

The first and the second stages of the industrial revolution span a period from 1760 till 1914.It is widely agreed to have begun in England and later spread to Europe and then to other countries.Previous industrial revolutions liberated human-kind from animal power, made mass-production possible, and brought digital capabilities to billions of people.

The third industrial revolution used electronics and information technology to automate production.The third industrial revolution created the foundational infrastructure for an emerging, collaborative age. The fourth industrial revolution is built on the third.

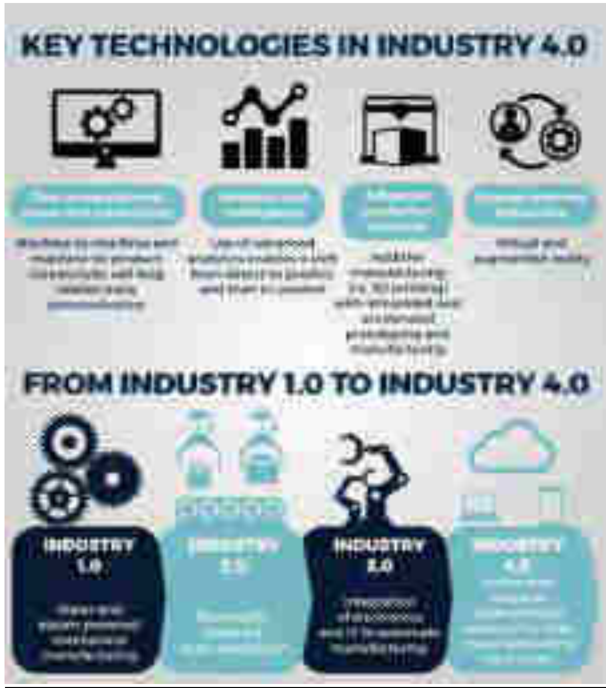


Fig 2.9: Phases Of Industrial Revolution

(Image source: ASEAN Post)

The fourth industrial revolution(Industry 4.0) is characterized by a fusion of technologies that is blurring the lines between the physical, digital and biological spheres. It is meant to impact all disciplines, economies and industries, and it even challenges the idea of what it means to be human. According to Professor **Klaus Martin Schwab**, founder and executive chairman of the **World Economic Forum**, and author of the "Fourth Industrial Revolution", the new age is differentiated by the speed of technological breakthroughs, the pervasiveness of scope and the tremendous impact of new systems.

In the fourth industrial revolution, the process is moving from electronic towards becoming a combination of human beings and electronics. Thus, processes like artificial intelligence have broken the distinction between man, machine and intelligence.The fourth industrial revolution is marked by emerging technology breakthroughs in a number of fields, including robotics, artificial intelligence; block chain, Nano-technology, quantum computing, biotechnology, the Internet of Things (IoT), 3D printing, and autonomous vehicles.

Like most software applications and electronic devices, the industry 4.0 refers to a software revision meant to indicate the overall shift towards digital platforms. It is in our hands to proactively shape the 4th industrial revolution As these fundamental transformations are underway in our society.The 4th industrial revolution needs to be more human centric and inclusive.

This revolution can be looked at as an opportunity to unite global communities and to build sustainable economies. **The 4th industrial revolution is therefore not a prediction of the future, but a call to action.**

Fig 2.10: INDUSTRY 4.0

(Image Source: Researchgate)

INDUSTRY 4.0 FROM INDIAN PERSPECTIVE:

The Fourth Industrial Revolution is a term that defines our present technological age.It is the fourth industrial era since the initial industrial revolution of the 18th century.

Recently, Prime Minister Narendra Modi gave an institutional shape to the expression, by launching the **center for the 4th industrial revolution- which is an initiative of the World Economic Forum.** This will initially focus on **artificial intelligence** and **machine learning**.

The fourth industrial revolution is marked by diverse technological breakthroughs due to fusion of technologies, ranging from physical to digital to biological spheres that bring together the fields of robotics, artificial intelligence, nanotechnology, biotechnology, and a host of others
India has become the fourth country in the world, where the World Economic Forum (WEF) had opened its Centre for the Fourth Industrial Revolution. With this, India will endeavor towards massive digital and technological transformation. The Centre for the Fourth Industrial Revolution India would work in collaboration with the NITI Aayog, to co-design new policies and protocols for emerging technologies with an initial focus on artificial intelligence, block-chain technology, and drones. Artificial Intelligence, Machine Learning, the Internet of Things (IoT), BlockChain Technology, Big Data, can act as a catalyst towards making India's growth story to newer heights. Many employment opportunities can be created that can make the lives of every Indian better.

The government is working to improve people's lives and prepare the youth for changing technologies through schemes like Atal Innovation Mission (AIM), Digital India, Skill India, Startup India, and others. Several areas where the fourth industrial revolution can help in transforming India like in the fields such as:

- Poverty alleviation;
- Better and low-cost healthcare;
- Doubling farmers' income with the help of new technology and equipment
- Improvement of infrastructure and connectivity to villages and remote towns
- Artificial intelligence can be used to empower and enable differently-abled people.
- It will improve the ease of living and the ease of doing business.

The fourth industrial revolution will usher in a series of social, political, economic, and cultural upheavals that will unfold over the 21st Century.

2.7 ARTIFICIAL INTELLIGENCE AND ROBOTICS

INTRODUCTION:

Artificial intelligence is an emerging technology that facilitates intelligence and human capabilities of sense, comprehend, and act with the use of machines. Some of the technologies that can allow these systems in analyzing and understanding all the information that is received are natural language processing and inference engines. Artificial Intelligence is a system that provides action through technologies such as expert systems and inference engines to undertake operations in the physical world.

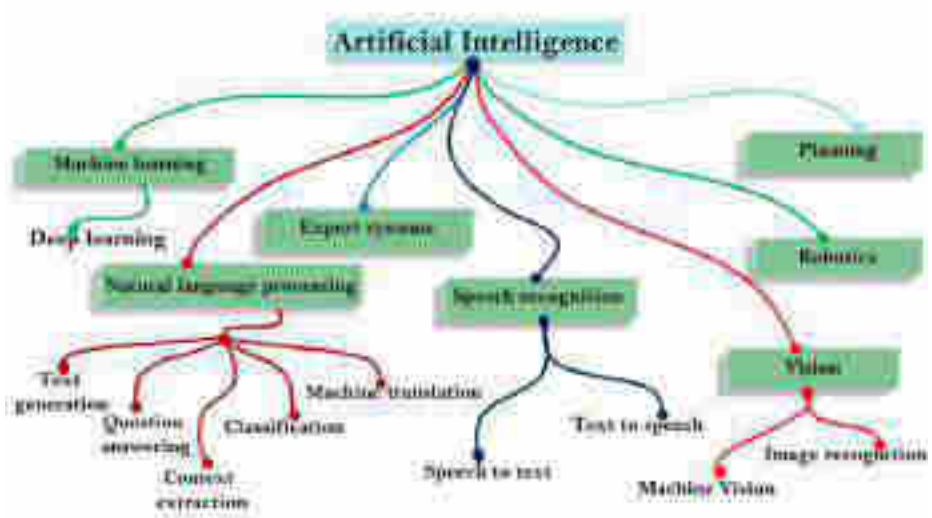


Fig 2.11: Artificial Intelligence

(IMAGE SOURCE: Down to Earth)

DEVELOPMENT IN ARTIFICIAL INTELLIGENCE

The economic and social benefits of applied AI are familiar in all the countries of the world.In the area of core research in AI and related technologies, universities and research institutions from the US, China and Japan have led the publication volume on AI research topics between 2010 and 2016. The AI Governance structures have the potential for enabling all the above mandates across countries. Many countries have instituted dedicated public offices such as the Ministry of AI (UAE), and Office of AI and AI Council (UK) while China and Japan have allowed existing ministries to take up AI implementation in their sectoral areas.

POTENTIAL OF ARTIFICIAL INTELLIGENCE:

Artificial Intelligence has the potential to provide sizable incremental value to a wide range of sectors globally and is expected to be the key source of competitive advantage for firms.

Healthcare	Transports, Logistics and Smart Mobility	Manufacturing	Smart Cities
AI plays an important role in the field of healthcare by addressing issues of high barriers particularly in rural areas that lack poor communication and professional healthcare systems. Some of the emerging application includes AI-driven diagnostics, personalised treatment, early identification of potential pandemics, and imaging diagnostics	This domain mainly includes various autonomous and semi-autonomous features, for example, monitoring and maintaining predictive engines along with driver-assist. Other applications of AI include improved traffic management, autonomous trucking and delivery.	It can enable 'Factory of the Future' through flexible and adaptable technical systems to facilitate various processes and machinery to respond to unfamiliar or unexpected situations by making smart decisions. Impact areas include · engineering, supply chain management, production, maintenance, quality assurance, and in-plant logistics and warehousing.	Incorporation of applied AI in developing cities could also help in meeting the demands of a rapidly growing population and providing them with enhanced quality of life. Traffic control for reducing congestion enhanced security by providing improved crowd management are some of the potential uses of AI system

Agriculture	Retail	Energy	Education and Skilling
AI has a major role to play in driving a food revolution and meeting the increased demand for food. Applied AI addresses challenges such as lack of assured irrigation, inadequate demand prediction, excess use of the pesticides, fertilisers and fungicides. Some uses include improved crop production through advanced detection of pest attacks, prediction of crop prices and real-time advisory.	Being one of the early adopters of AI solutions, it provides applications such as developing user experience by personalized suggestions, image-based product search and preference-based browsing. Other uses include customer demand anticipation, improved inventory management, and efficient delivery management	The potential use of Artificial Intelligence also includes modelling and forecasting of the energy system to reduce unpredictability. AI also focuses on increasing the efficiency of power balancing and enabling the storage of energy in renewable energy systems. This process uses smart meters to enable intelligent grids, thus, improving the affordability and reliability of solar energy. Apart from these, AI may also be deployed for predictive maintenance of grid infrastructure.	AI plays a major role in the Indian education sector by providing solutions for quality and access issues including augmentation and enhancement of the learning experience through personalized learning, automating and expediting administrative tasks, and predicting the need for student intervention to reduce dropouts or recommend vocational training.

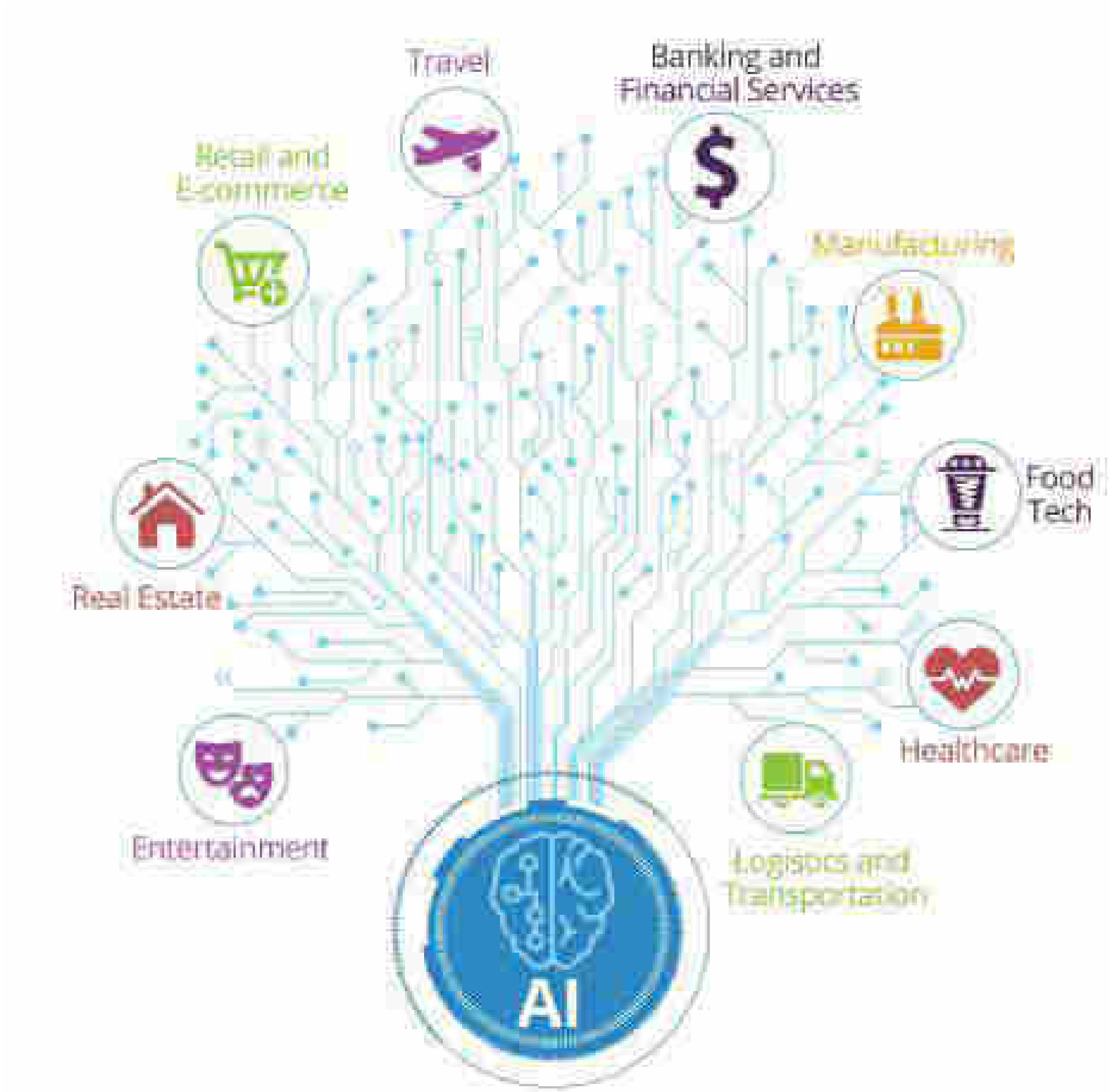


Fig: 2.12: AI: APPLICATIONS

(*IMAGE SOURCE: Dzone.com)*

CHALLENGES WITH ARTIFICIAL INTELLIGENCE IN INDIA

- **Absence of collaborative effort** between various stakeholders
- **Concerns on privacy and security** of data, including lack of formal regulation around anonymisation of data.

- **Lack of sufficient talent** to build and deploy AI systems at scale. An estimate claims that only 4% of AI professionals in India have worked on emerging technologies such as deep learning and neural networks. There is also a significant gap in PhD research scholars in the field.
- **Difficulty in access to industry-specific** data required to build customised platforms and solutions is currently in the hands of a few major players. It is challenging for new beginners to provide customised services that can compete with the existing data that includes rich incumbents such as Facebook or Google. This phenomenon results in the creation of a virtuous cycle which reinforces the hegemony of the big few, creating a huge entry barrier for start-ups.
- **High cost and low availability** of computing infrastructure required for development, training and deployment of AI-based services. Cloud infrastructure, though growing rapidly, has limited capability.
- **Lack of infrastructure** is the major reason for many Indian AI start-ups that aim to incorporate their business outside the country, thus, making AI outside the reach of Indian researchers in government labs and many industries. Initiatives like GI Cloud (MeghRaj), are in the right direction.
- **Lack of AI awareness** in resolving business-related issues in most of the public enterprises and government agencies has led to the scarcity of AI professionals in obstructing adoption.

THREATS ASSOCIATED WITH AI

- **Data Protection**: one of the most important challenges to adopting AI is the question of data security. The data stored or assimilated in the AI systems can fall into the wrong hands and the repercussions could be catastrophic.
- **Understanding**: The AI systems are built based on algorithms, which can be far too technical for the common man to understand. This makes it difficult for the public to understand its functioning too.
- Lack of enabling data ecosystems
- The low intensity of AI research
- Core research in fundamental technologies

- Transforming core research into market applications
- Lack of AI expertise, and manpower skills
- Uncertain privacy, security, and ethical regulations
- **Data democratization**
- Unattractive Intellectual Property regime to incentivize research and adoption of AI
- It can result in the replacement of **manpower**.

Apple and most of the Chinese brands of mobile phones have facial recognition technology imbibed in their software. This could lead to the possibility of “mass surveillance”, which also violates the privacy concerns of an individual.

The assimilated data in the AI systems could be passed onto the wrong hands which can prove to be a threat to national security.

The increasing reliance on the use of machines, machine learning, and the use of smart algorithms to power artificially intelligent systems, makes it prudent to regulate AI. The regulations should be focussed on the intended usage of the technology rather than restricting the usage of the technology itself.

WAY FORWARD TO HARNESS THE POWER OF AI-BASED TECHNOLOGY:

- **Instigating Core and Applied Research in AI:** Advanced research, both core and applied, provides the basis for commercialization and utilization of any emerging technology, more so for technologies like AI. A considerable amount of dedication and effort is required to build comprehensive research focusing on AI strategy for India.
- **Getting India ready for the AI wave**: India may appear to be relatively well-positioned to take advantage of the disruption in AI system through its advanced IT sector and large youth demographic potential to establish itself as the future hub for AI-related activities. However, given the reduced availability of qualified faculty and researchers, this advantage could quickly change into a liability without urgent government interventions towards promoting access to such skills. This is a critical component of AI development and should be a national priority.
- **Accelerating Adoption**: Adoption of AI in India has been slow and remains limited. Estimates indicate that only 22% of the firms in India use AI in any business process. Government intervention is needed to promote AI adoption, lest India loses the chance to

secure a prominent position on the global AI map. While acknowledging the need to improve AI, governments at different levels, along with their various instrumentalities, should adopt proactive measures to accelerate AI adoption in multiple processes.

- **Ethics, Privacy, Security, and Artificial Intelligence**: AI is going to be the tipping point in the technological evolution of mankind, with human dependence on machines and algorithms for decision making never been so profound. Thus, any strategy document on promoting AI necessarily needs to be conscious of the probable factors of the AI ecosystem that may undermine ethical conduct, impinge on one's privacy, and undermine the security protocol. Appropriate steps to mitigate these risks need to be an integral part of any such strategy. E.g., National Cyber Security Policy (NCSP – 2013) talks about the Sensitization of citizens, consumers, and employees on cybersecurity threats and basic and best practices Sensitization towards the safety of cyber threats and in pursuance of security programs.

These challenges, if addressed by relevant stakeholders, with the government playing a leading role could lead to fundamental building blocks that form the core to India's march towards leadership in AI in an expeditious manner through concerted and collaborative efforts.

ROBOTICS

Robotics relates to the industry that deals with the engineering, design, manufacture, and operation of robots for various commercial industries and consumer uses. Robotics also refers to a branch of engineering that deals with the conceptualization, designing, manufacture, and operationalization of robots.

Robotics is an interdisciplinary branch that consists of various fields of engineering as well as artificial intelligence, nanotechnology bioengineering, etc.

Developments Related to Robotics

Robots have become an essential component of many modern manufacturing industries. As the modern manufacturing industries increase the use of robots, the number of jobs performed by robots is steadily rising. The use of robots in industries has increased their efficiency and productivity, and today robots are seen as a long term investment for benefactors.

All these developments have increased the concern over unemployment due to the risk of automation. According to a study, 47% of US jobs are at risk of automation over some unspecified number of years. However, the claims on artificial intelligence and robotics causing unemployment have been criticized on the ground that social policy and not artificial intelligence is responsible for this. Robotics and Robots present both challenges and opportunities for occupational safety and health. The benefits include the substitution of humans with robots in unhealthy and dangerous environments.

Robots are useful in space, defense and security, nuclear industry, logistics, maintenance, and inspection. They can replace humans performing a dirty, dull, and unsafe task and avoid workers' exposure to hazardous conditions and reduce risks. For example, robots are used for handling radioactive materials and for working in an explosive atmosphere.

Despite these advancements, there are certain skills to which only humans will be better suited, and therefore, it is important to achieve the best combination of robot and human skills.

The advantages of humans include creative decision making, flexibility and adaptability, whereas robotics has the advantage of performing heavy-duty jobs with precision and repeatability.

This combination of humans and robots sharing a common workplace has led to the development of new standards and approaches for ensuring the safety of the “man-robot merger”.

In the future, the cooperation between humans and robots will diversify into new forms. The current approaches and technical standards for the protection of employees from the risk of working will have to be revised.

Advantages of Robots:

- It is believed that recent developments in the robotics world have made robots more user friendly, intelligent, and most importantly, affordable. With these benefits of robotics, it is no wonder that they have found jobs in every field. That is right, from industrial manufacturing to the medical field robots are being used.
- The benefits of robots have increased their flexibility by being capable of performing a variety of tasks and applications. They are more precise and consistent than human

workers. Robots also allow for increased production and profit margins because they can complete tasks faster. Robots can work around the clock since they do not require vacations, sick days, or breaks. They also make fewer mistakes than humans, saving companies time.

- Other benefits of robotics are that they can work in any environment, adding to their flexibility. Robots eliminate dangerous jobs for humans because they are capable of working in hazardous environments. They can handle lifting heavy loads, toxic substances, and repetitive tasks. This has helped companies to prevent many accidents, also saving time and money.
- In the medical field, robots are used for intricate surgeries such as prostate cancer surgery. Robots can reach and fit where human hands cannot, allowing greater accuracy. Some robotic benefits in the medical field are less invasive procedures and less pain for the patient when recovering.
- Their ability to be customized provides companies with the flexibility to use them for a variety of tasks.

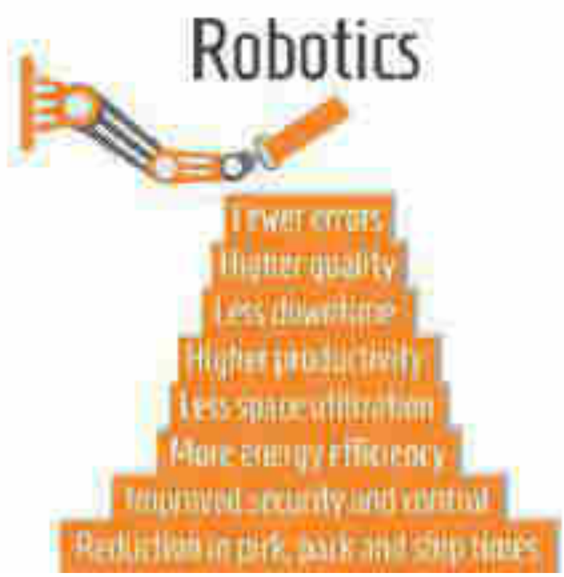


Fig 2.13: Benefits of Robotics

(Image source: plastvision.org)

Disadvantages of Robotics

- There are issues regarding job losses of people as also the extensive consumption of energy
- Moreover the cost associated with Development of software or techniques for robotics may be too high.
- Robots cost much money in maintenance & repair. The programs need to be updated to suit the changing requirements, and the machines need to be made smarter, In case of breakdown, the cost of repair may be very high, The procedures to restore lost code or data may be time-consuming & costly.
- The robot is not able to act any different from what they are programmed to do. With the heavy application of robots, the humans may become overly dependent on the machines, losing their mental capacities. If the control of robots goes in the wrong hands, Robots may cause destruction.
- They are not intelligent or sentient, and They can never improve the results of their jobs outside of their predefined programming. They do not think, They do not have emotions or conscience, This limits how the robots can help & interact with people.
- Robots can take the place of many humans in factories, So, the people have to find new jobs or be retrained, They can take the place of the humans in several situations, If the robots begin to replace the humans in every field, They will lead to unemployment.
- Robots inspire two types of fear: firstly, that they might take over our jobs, and secondly, that they could take over the world, Robots will steal our jobs, Robots have the effect of increasing productivity rather than eliminating jobs.
- Robots become increasingly present in our everyday life, with household robots, medical, industrial, on production lines, not to mention airports, banks, and hotels, So, Robots may dominate the human species. Robots can operate on the basis of information fed to them through a chip; when one thing goes wrong, the entire company bears a loss.
- Although They can save times, it can also result in a lag, It is a machine so you can't expect too much from them, If the robot has malfunctioned, you need extra time to fix it, which would require reprogramming, If robots would do all the work, and the humans will just sit and monitor them, health hazards will increase rapidly, Obesity will be on top of the list and less labour at workplaces.

Applications of Robotics:

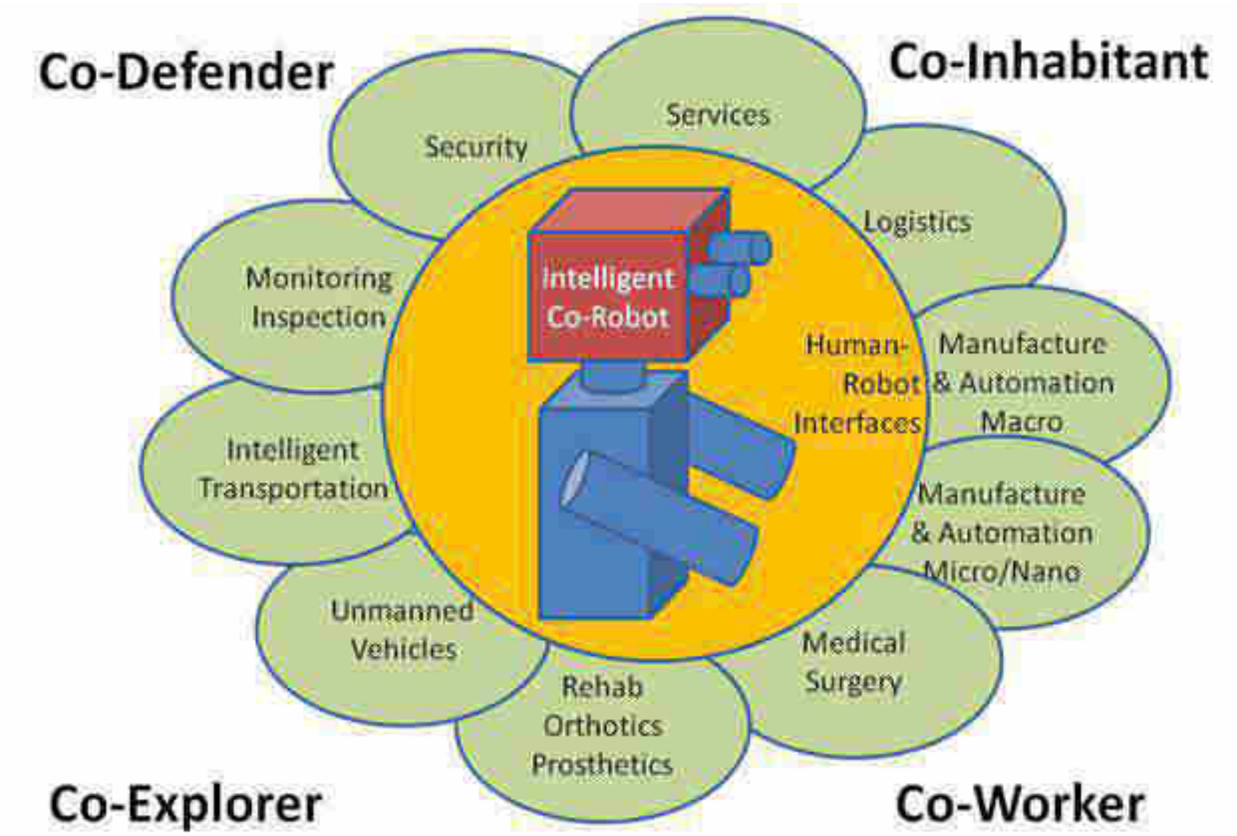


Fig 2.14: Various Fields For Applications

(Image source: National Science Foundation)

2.8 CYBORG

Cyborg can be considered as the real version of technological advancement that was once considered as fiction. The term cyborg was first coined in 1960. The scientists described cyborg as a man-machine system in which the control mechanisms of the human portion are modified externally by drugs or any other device so that the man can be able to live in an environment different from the normal one.

Cyborg is a short version for the cybernetic organism. Although an older term, modern research and increased use of technology in biomedicine make cyborg the future of human development. As the name suggests, cyborg consists partly of humans and part machines. Those people who are having a cardiac pacemaker, contact lenses or implants come under the cyborg.

The last two decades see the ever-fast pace in the development of cyborgs. Various successful implantation like embedment of the antenna inside the skull, bionic limb connection through nerve-muscle grafting and many others show that cyborg does not remain merely a fiction that we see in comics like Justice League and Avengers, but it's a modern world reality.

Cyborg is said to be an open field by modern scientists. As technology advances, more and more augmentation of the body with machines will occur. This augmentation, no doubt, will make humans more agile and stronger. However, all this will also impact the basic behaviour of human beings. The effect may both be positive as well as negative. Therefore, there exist serious ethical issues in this regard.

This augmentation will make humans more agile and stronger. However, all the effect may both be positive as well as negative. Therefore, there exists serious ethical issues in this regard.

Challenges

- Firstly, artificial limbs do not provide a sense of touch that connects us with our family or allow us to feel the outer world as before. The real cause is less evolution in the field of development of sensing skin.
- Secondly, as we have already discussed that there exists a serious ethical dilemma in the future of cyborg, there are many people with implants inserted in their bodies to increase the innate human capacities, both mental and physical. All these activities may redefine the meaning of humanness, the change that may cause problems.
- They have a limited lifespan thus issues of durability, replacements may arise that may complicate the problems.

The cyborg technology has already taken the next stage of integration beyond the medical field. The machines are not serving merely as an alternative to the human body part. The cyborg technology is setting the stage for the next chapter of human evolution. The contemporary field of cyborg research lies in the brain-machine interface. Any breakthrough may change our view of humanity.

The criticism and problems associated with cyborg cannot be avoided. However, the solution lies not in closing, but in more responsible and ethical research in this field. Keeping this in mind, the first Cyborg Olympics were organized in Zurich, Switzerland, in 2016. It was the first time that the official celebration of cyborg sports was conducted. It is believed that cyborgs are the next step in human evolution of mankind. The establishment of colonies on different planets is imminent in the near future, and so is the development in cyborg technology. There is a need for all the ethical and moral questions to be resolved over the global stage. Like all other inventions, the cyborg can work both as a boon or a bane, and the choice is ours.

2.9 SUPERCOMPUTERS

INTRODUCTION

Supercomputers,comparatively ,have a very high level of computing performance with respect to general purpose computers and their performance is generally measured in FLOPS (floating point operations per second) . These computers are known for their high level of memory and performance speeds.Their performance is generally evaluated in petaflops (1 followed by 15 zeros). Supercomputers have utilities in solving problems that are too complex and huge for standard computers.

SUPERCOMPUTERS IN INDIA

India started its journey towards supercomputers because of the denial by USA to export Cray supercomputers due to the arms embargo imposed on India after Nuclear tests in the 1970s. It was believed that India might use the supercomputers for the development of military purposes since supercomputers came under dual-use technology groups.

Ideation phase was started in the 1980s.

India developed its first indigenous supercomputer in the year 1991. The Centre for Development of Advanced Computing was instrumental in this which named the supercomputer as PARAM 8000. It was assisted by Russia in this project.

PARAM 8000 was replicated and installed at ICAD Moscow in 1991 under Russian collaboration.In 2007, India held top 10 spots for speeds of supercomputers.India has nine supercomputers with speeds in top 500 but not any in top 10.

It unveiled PRATYUSH and MIHIR ,one of the worlds' fastest supercomputers under its **National Supercomputing Mission.**

NOTE:- Summit (USA), **Sunway TaihuLight** And **Sierra** are the top three Supercomputers of the world.

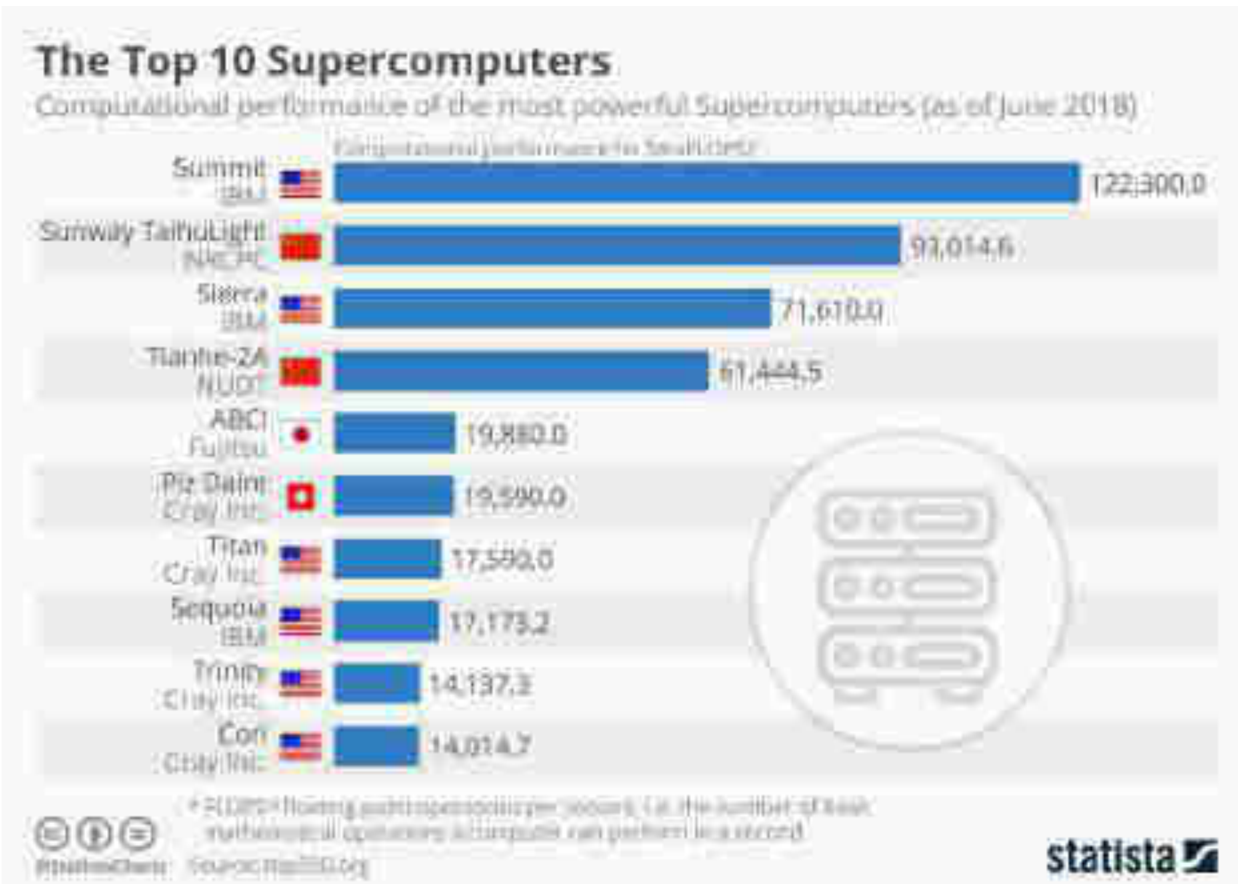


Fig 2.15: World's Fastest Supercomputers

(Image source: statista)

2.10 NATIONAL SUPERCOMPUTING MISSION

National Supercomputing Mission, is a mission of the Government of India to boost the supercomputing capabilities of India.

- This mission consists of designing and manufacturing 73 supercomputers in India.
- These clusters of supercomputers will be connected to various academic and research institutions across India. This grid will be connected to the National Knowledge Network (NKN).
- This is a Rs 4,500 Crore project.
- In 2018, the Government of India awarded a contract to French company Atos to build supercomputers under this mission. Atos has collaborated with Indian partners in Chennai and Pune to build most of the required parts.

Currently, Pratyush and Mihir are the Fastest Supercomputers in India. These are the 2 High-Performance Computing Units (HPC) with a combined speed of 6.8 PetaFlops. Pratyush is established in Indian Institute of Tropical Meteorology (IITM), Pune. Mihir is established in the National Centre for Medium-Range Weather Forecast (NCMRWF), Noida.

Pratyush and Mihir are used for the following applications:

- Weather forecasting
- Air quality
- Fishing
- To detect natural calamities

The Nodal Agencies for the Mission are :

- **Department of Science and Technology (Government of India)**
- **Department of Electronics and Information Technology (DeitY)**
- **Centre for Development of Advanced Computing (C-DAC)**
- **Indian Institute of Science (IISc)**

The Supercomputers which will be developed under the mission can be used for many new-age applications. Few examples are given below:-

- Weather forecasting
- Natural disaster predictions
- Drug discovery
- Space applications

- Aerodynamic research
- 3D nuclear test simulations.

2.11 QUANTUM COMPUTING

INTRODUCTION:

A group of physicists including Max Born, Wolfgang Pauli and Werner Heisenberg in the early 1920s at the University of Göttingen had coined the term “Quantum Mechanics”. The gradual acknowledgment by scientists that matter has wave-like properties and radiation has particle-like properties provided the momentum for the development of quantum mechanics.

It is the branch of physics that deals with the behavior of light and matter on a subatomic and atomic level. It attempts to explain the properties of atoms and molecules and their fundamental particles like protons, neutrons, electrons, gluons, and quarks. The properties of particles include their interactions with each other and with electromagnetic radiation.

Quantum mechanics is here to stay and taking it as a thing of the past will be a mistake. Till now it was not as popular but recently,. Quantum mechanics has been applied and accepted into many fields like thermodynamics, cryptography,optics, computers and also meteorology. Research is going on in these fields.

QUANTUM MECHANICS AND COMPUTERS:

Computers have come a long way since their inception in the 18th century (The Analytical Engine). Today Computers have become so powerful that they can do the mathematical and scientific high performing millions of calculations every second, predicting the weather and also, beating humans at chess, which has been possible due to Advancements in technology.

Fundamentally, a normal computer can encode information as a string of binary digits consisting of 0s and 1s. Quantum computers take this to the next level with “Qubits”, bits that equal 0s and 1s at the same time. What this means is it can perform certain tasks like molecular modeling and factoring numbers much faster than an ordinary computer.

Quantum computers are different from binary digital electronic computers that are based on transistors (a semiconductor device used to amplify or switch electronic signals and electrical power). The common digital computing requires the data to be encoded into binary digits (bits), each of which is always in one of two definite states (0 or 1).

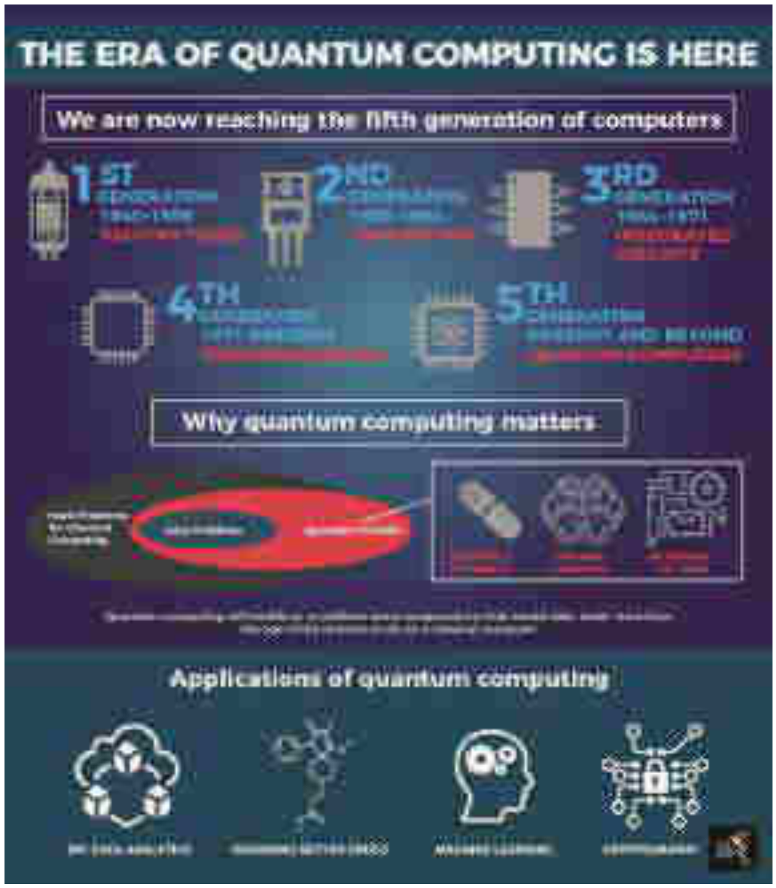


Fig 2.16: Quantum Computing

(Image source: IBM)

Working of Quantum Computers:

- They work according to two key principles of quantum physics: **superposition** and **entanglement**.
- When each qubit can represent both a '1' and a '0' at the same time it is known as superposition.

- When qubits in a superposition state can be correlated with each other; that is when states of qubits are interdependent,it is called entanglement.
- It means that particles remain connected so that actions performed on one affect the other, even when separated by great distances. Albert Einstein had called this phenomenon "spooky action at a distance."
- With these two principles,the qubits enable quantum computers to solve difficult problems that are unmanageable using today’s computers.

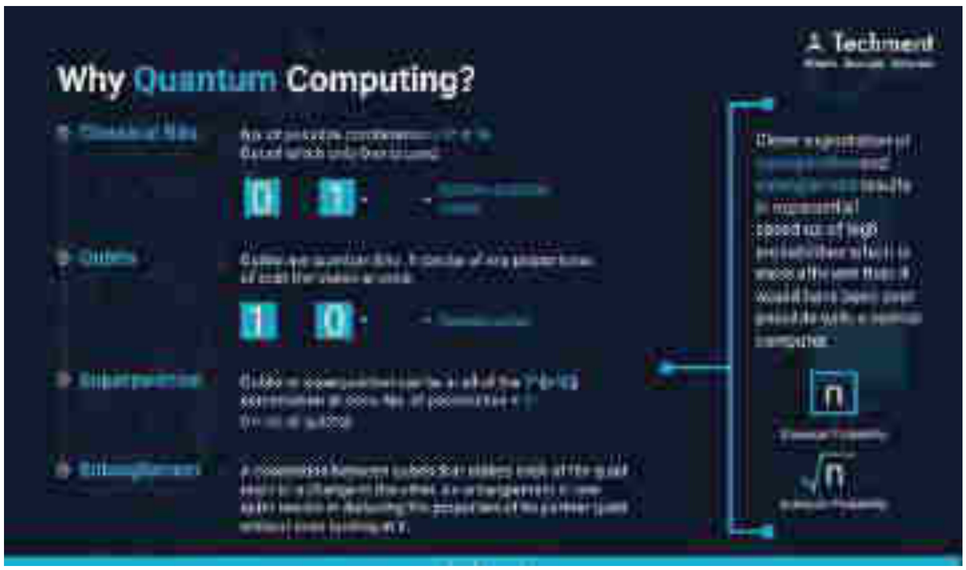


Fig 2.17 QUANTUM COMPUTING

(Image source: IBM)

QUANTUM SUPREMACY

In quantum computing, quantum supremacy refers to quantum computers being able to solve a problem that a classical computer cannot.

In the year 2011 by John Preskill, Professor of Theoretical Physics at the California Institute of Technology, coined the term ‘quantum supremacy’.

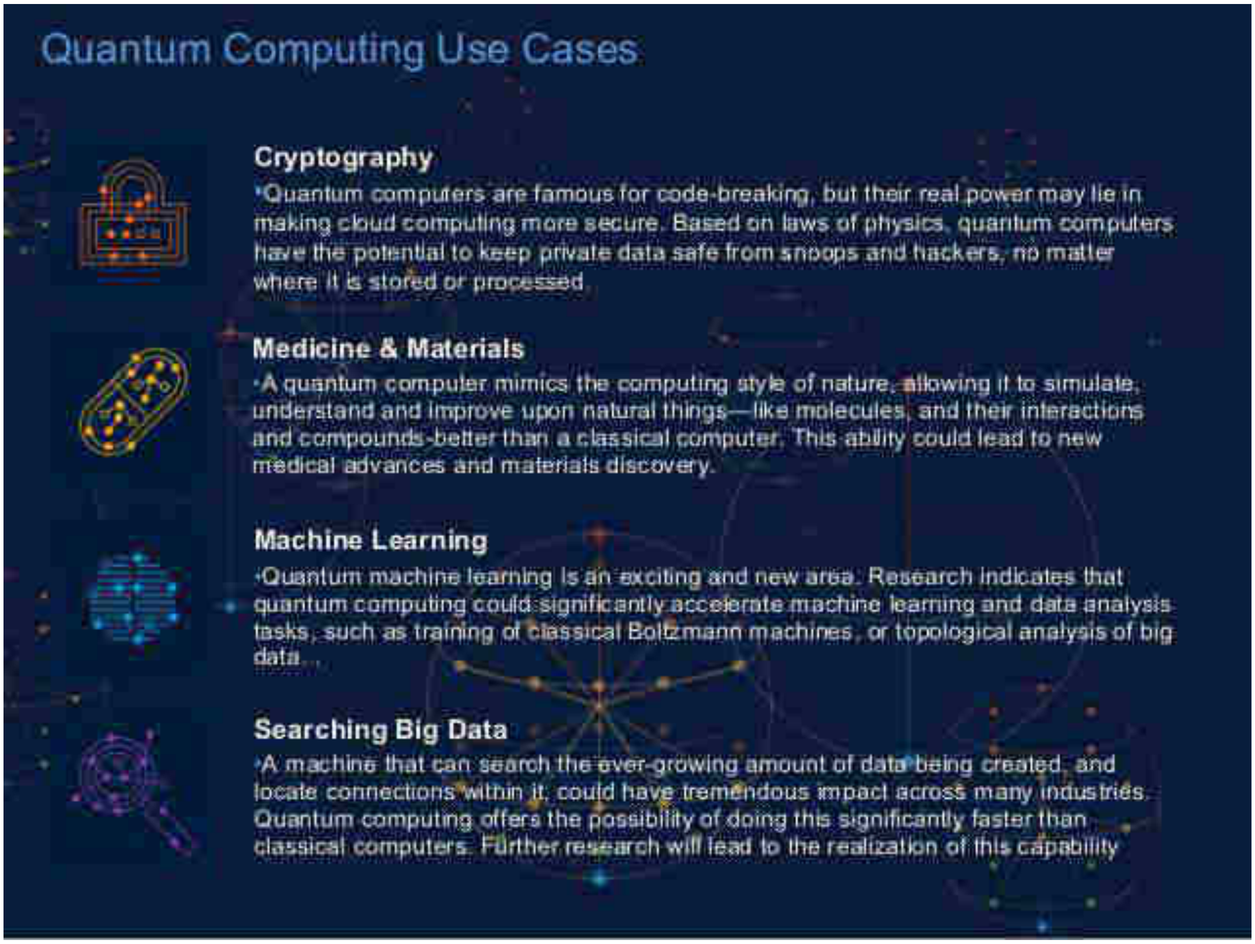


Fig 2.18 QUANTUM COMPUTING (UTILITIES)

(Image source: Enabler space)

INDIAN INITIATIVE

- In 2018, the Department of Science & Technology unveiled a program called Quantum-Enabled Science & Technology (QuEST) and committed to investing ₹80 crores over the next three years to accelerate research. The ostensible plan is to have a quantum computer built in India within the next decade.

- National Mission on Quantum Technologies & Applications (NM-QTA):
    - India has joined a select few countries that chase “Quantum Supremacy” with an Rs 8,000-crore national mission to crack into the next-generation technology, which promises exponential ‘compute’ power and to rewrite the rules of present-day computing.

- The Department of Science and Technology will build a homegrown 50 Qubit 'Quantum Computer' in 4-5 years as part of the mission, which will also include building solutions for quantum communications, storage and encryption.
- Quantum technologies are rapidly developing globally with huge disruptive potential. The next-generation transformative technologies that will receive a push under this mission include quantum computers and computing, quantum communication, quantum key distribution, encryption, cryptanalysis, quantum devices, quantum sensing, quantum materials, quantum clock and so on. The areas of focus for the Mission will be in fundamental science, translation, technology development, human and infrastructural resource generation, innovation and start-ups to address issues concerning national priorities.
- The Mission will be able to address the ever-increasing technological requirements of the society and take into account the international technology trends and road maps of leading countries for the development of next-generation technologies.

Significance of the mission:

Implementation of the mission would help develop and bring quantum computers, secure communications through fiber and free space, quantum encryption and crypt-analysis, and associated technologies within reach in the country and help address India specific national and regional issues.

The mission will help prepare next-generation skilled manpower, boost translational research and also encourage entrepreneurship and start-up ecosystem development. By promoting advanced research in quantum science and technology, technology development and higher education in science, technology and engineering disciplines India can be brought at par with other advanced countries and can derive several direct and indirect benefits.

RECENT DEVELOPMENTS IN FIELD OF INFORMATION COMMUNICATION TECHNOLOGY(ICT)

1. Digital India Mission:-

The Indian Government launched the Digital India campaign to make available government services to citizens electronically by online infrastructure improvement and also by enhancing internet connectivity. It also aims to empower the country digitally in the domain of technology. Prime Minister Narendra Modi launched the campaign on 1st July 2015.

Digital India was an initiative taken by the Government of India for providing high-speed internet networks to rural areas.

2. Vision of Digital India:

Digital India Mission is mainly focused on three areas:

- Providing digital infrastructure as a source of utility to every citizen.
- Governance and services on demand.
- To look after the digital empowerment of every citizen.

Digital India was established with a vision of inclusive growth in areas of electronic services, products, manufacturing and job opportunities.

There are major nine pillars of Digital India are:

<u>Fig 1.1: Components of Digital India</u>

(Image source: Pib)

In the last 4 years since its launch several achievements have been made under the Digital India Mission as given below:

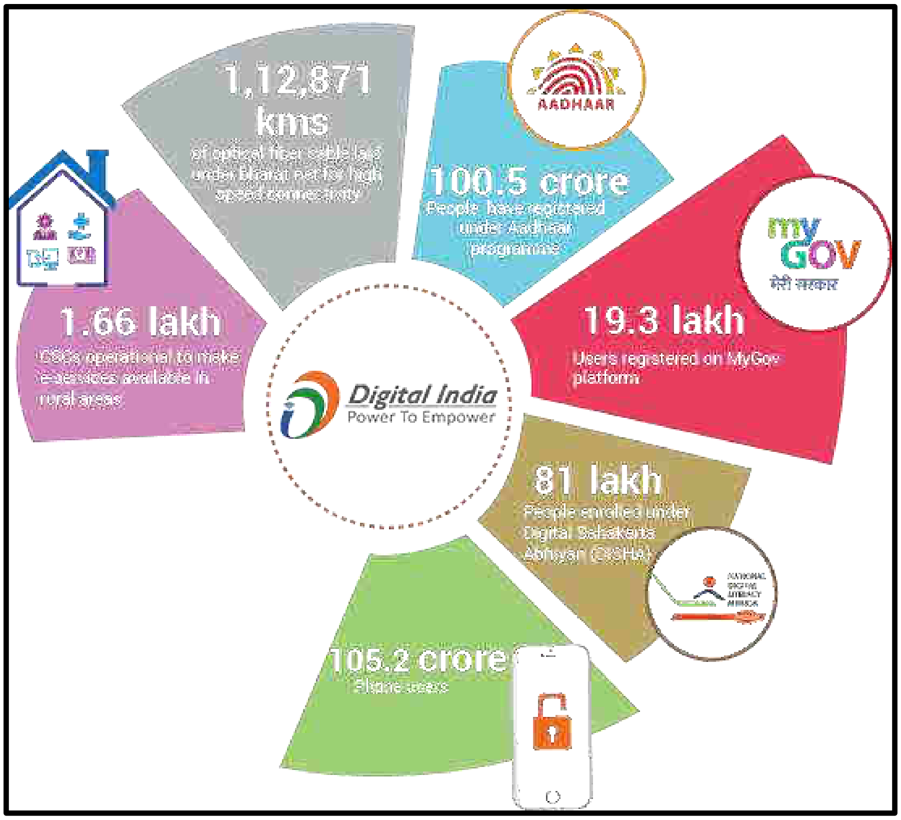


Fig 1.2: Achievements Under Digital India

(IMAGE SOURCE:MYGOV)

Objectives of Digital India:

The motto of Digital India Mission is **'Power to Empower'**. While there are three core components to the Digital India initiative. They are - **digital infrastructure creation**, **digital delivery of services** and **digital literacy**.

The major objectives of this initiative are listed below:

- To provide high-speed internet in all gram panchayats.
- To provide easy access to the Common Service Centre (CSC) in all the localities.
- Digital India is an initiative that combines a large number of ideas and thoughts into a single, comprehensive vision so that each of them is seen as part of a larger goal.
- The Digital India Programme also focuses on restructuring many existing schemes that can be implemented in a synchronized manner

Advantages of Digital India Mission:

Digital India Mission is an initiative that encompasses plans to connect the rural areas of the country with high-speed internet networks. On the platform of digital adoption, India ranks amongst the top 2 countries globally and the digital economy of India is likely to cross $1 trillion by the year 2022.

Some of the advantages of Digital India are:

- Around 12000 post office branches in the rural areas have been linked electronically.
- There is an increase in electronic transactions related to e-governance.
- Optical fiber network of 2, 74,246 km has connected over 1.15 lakh Gram Panchayats under the Bharat Net programme.
- A Common Service Center (CSC) is created under the National e-Governance Project of the Indian government which provides access for information and communication technology (ICT)., the CSCs provide multimedia content related to e-governance, education, health, telemedicine, entertainment, and other government and private services with the help of computer and internet access.
- Digital villages along with well-equipped facilities such as solar lighting, LED assembly unit, sanitary napkin production unit and Wi-Fi choupal will be set up under the mission.
- Delivery of services with the internet and other digital technologies and the urban internet penetration has reached 64%.
- Presently, the number of daily active internet users has reached 300 million from 10-15 million daily users. Also, it is estimated that the number would double by the year 2020.

Challenges of Digital India:

The Government of India has taken an initiative through the Digital India Mission to connect the rural areas of the country with high-speed internet networks. Apart from the various initiatives taken by Digital India, there are several challenges faced by it.

Some of the challenges and drawbacks of Digital Mission are mentioned below:

- The daily internet speed, as well as the Wi-Fi hotspots, are slow as compared to other developed nations.

- Adapting to the new modern technology.is an issue for Most of the small and medium scale industry has to struggle a lot for
- Lack of sufficient availability of smartphones with digital enabled technology.
- Lack of enough skilled manpower in the field of digital technology.
- Cyber security is a concern with rising cases of frauds
- Lack of digital education.

NATIONAL DIGITAL COMMUNICATIONS POLICY (2018)

INTRODUCTION:

As the present world has entered the era of modern technological advancements in the Telecom Sector such as 5G, loT, M2M etc., a need was being felt to introduce a 'customer focused' and 'application driven' policy for the Indian Telecom Sector, which can form the main pillar of Digital India by addressing emerging opportunities for expanding not only the availability of telecom services but also telecom based services. Thus in place of the existing National Telecom Policy-2012, a new National Digital Communications Policy - 2018 has been formulated, to cater to the modern needs of the digital communications sector of India.

The policy envisions India's transition to a digitally empowered society and information/knowledge economy and in this light it seeks to fulfil the information and communications needs of citizens and enterprises by establishment of affordable digital infrastructure,.

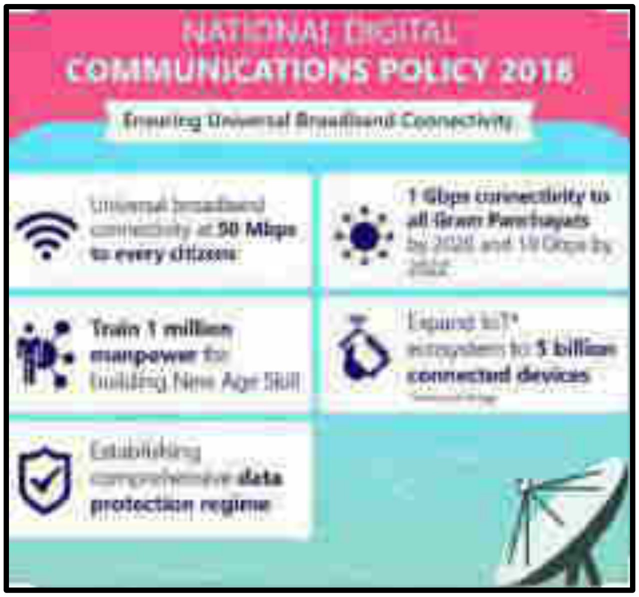


Fig 2.1 National Digital Communications Policy

(Image source: Mygov.in)

Objective of the Policy

These objectives are to be achieved by 2022:-

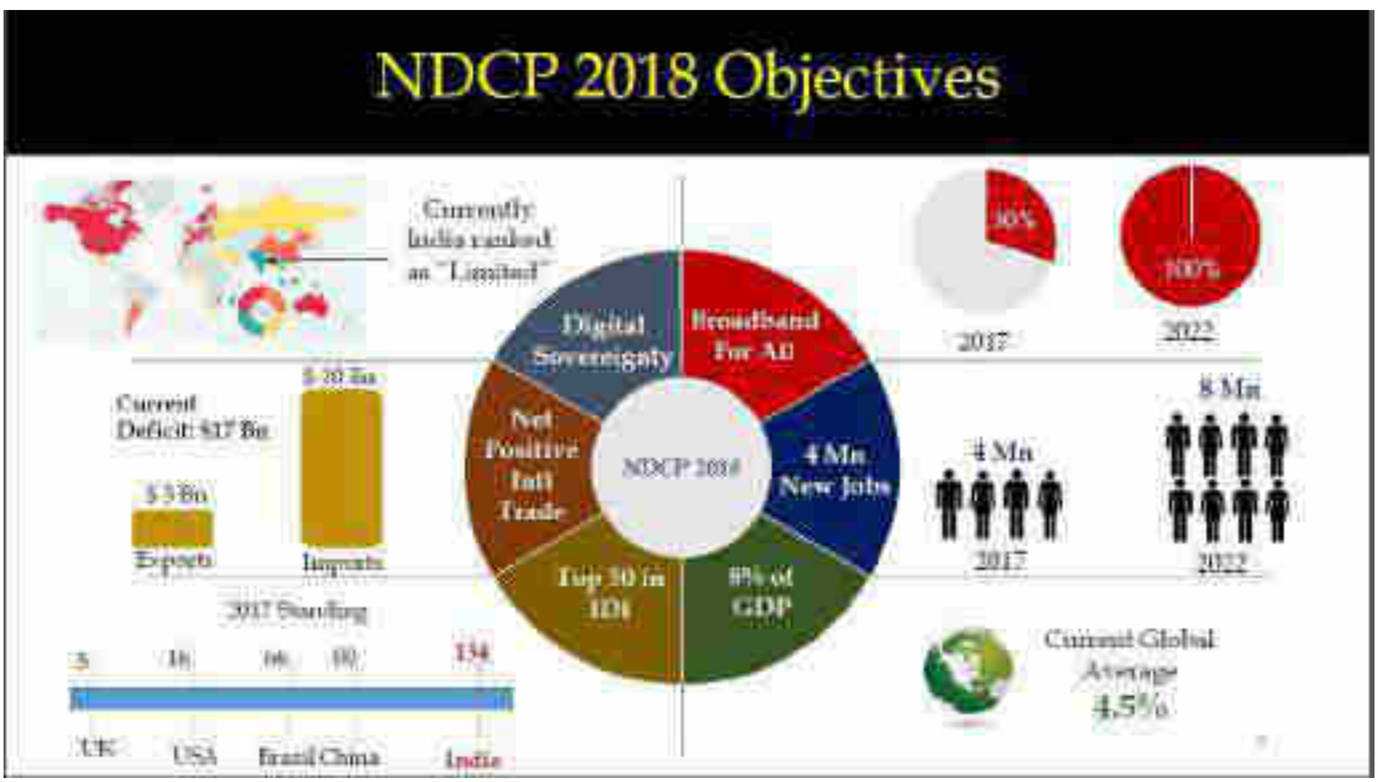


Fig 2.2 Objectives of NDCP-2018

(Image source: Inc42.com)

2.3 <u>Features of The Policy:</u>

The policy aims to

- Provide universal broadband connectivity at 50 Mbps to every citizen;
- Provide 1 Gbps connectivity to all Gram Panchayats by 2020 and 10 Gbps by 2022;
- Ensure connectivity to all uncovered areas;
- Attract investments of USD 100 billion in the Digital Communications Sector;
- Train one million manpower for building New Age Skill;
- Expand IoT ecosystem to 5 billion connected devices;
- Establish a comprehensive data protection regime for digital communications that safeguards the privacy, autonomy and choice of individuals
- Facilitate India's effective participation in the global digital economy;
- Enforce accountability through appropriate institutional mechanisms to assure citizens of safe and
- Secure digital communications infrastructure and services.

<u>Strategy under the Policy:</u>

CLOUD COMPUTING

INTRODUCTION

According to a recent report, more than a million jobs will be created in the Cloud Computing sector of India by 2022. The area of cloud computing is rapidly becoming more prevalent and dominant in both small scale medium and large businesses and companies. Also, it could be seen that large businesses and firms are gradually investing heavily in the cloud infrastructure and the sector is expected to grow very fast by the year 2022.

There has been a growing application of Cloud computing in India in the last few years as they are used in everyday activities of people such as social networking, mail, online purchases, and large-scale operations of MNCs including big data, Internet of Things (IoT), etc.

It has been realized by the Government and Indian Private Businesses that it offers huge potential for firms to grow, expand, and is opening up new windows of opportunities not only locally but also globally. Several sectors like retail, banking, manufacturing, railways, education, and healthcare among Others have started the adaptation of cloud services.

CLOUD COMPUTING:

Cloud computing relates to delivering hosted services over the internet. The cloud computing process involves providing a pool of shared resources like networks, servers, storage, applications, and services that can be provided to the consumer rather than the consumer managing them on her own which is costly and time-consuming. The Internet is at the core of the evolution of this technology.

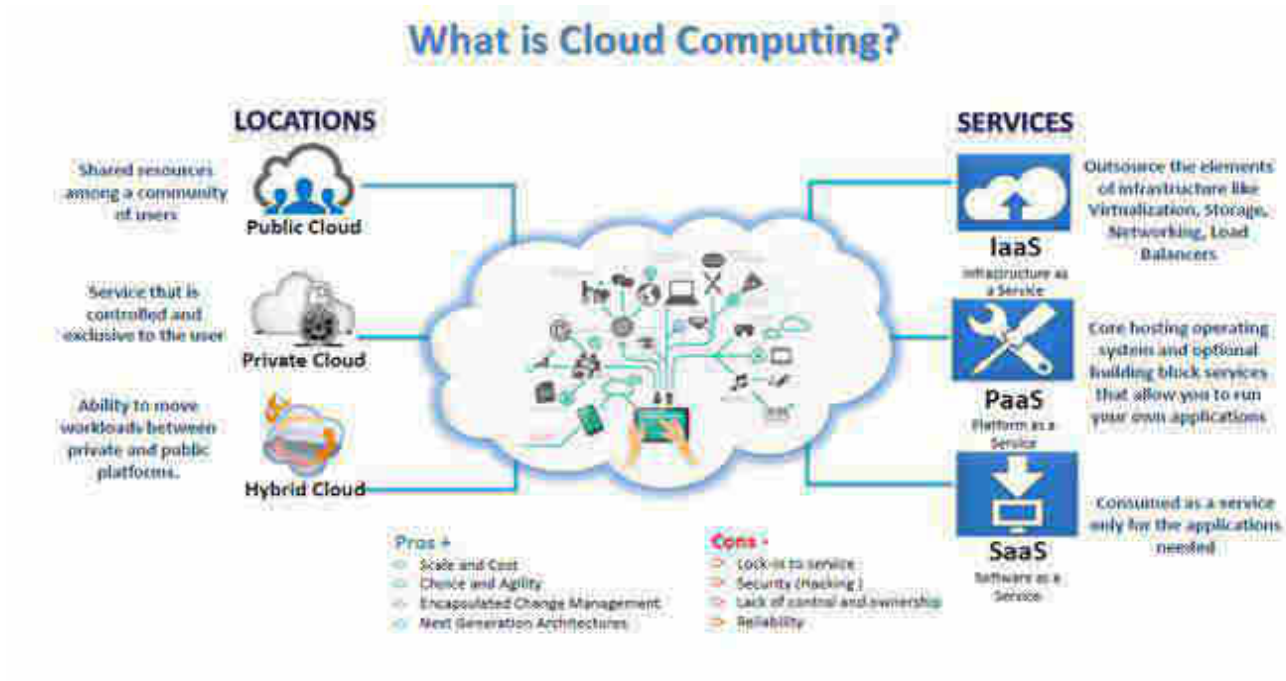


Fig 3.1: Cloud Computing

(image source:dataflair.training)

Features of Cloud Computing:

Fig 3.2 :Cloud computing features

(Image source: Data flair)

Benefits of Cloud Computing:

Improved disaster recovery	**Disaster recovery can be made possible by Moving the business data to the cloud ie., retrieving data in case of a hardware compromise.**
Cloud computing services minimize IT requirements and physical storage, which helps small businesses cut significant business costs.	**Environmental friendly as Carbon footprint is minimised due to low energy consumption**

Disadvantages of Cloud Computing:

Issues of high maintenance Cost	**Security as Companies with sensitive data will require their own IT department to keep data secure because when the data is stored in the cloud, the company is trusting a third party to keep it safe.**	**Need of Continuous internet connectivity**	**There are challenges of integrating cloud computing at smaller scale and adaptability of Small-scale companies and servers is still a question**

BHARAT-NET PROJECT

INTRODUCTION:

BharatNet Project is the world's largest rural broadband connectivity program using Optical fiber. It is implemented by Bharat Broadband Network Limited (BBNL) – a special purpose vehicle under the Telecom Ministry and is the Government of India's ambitious rural internet connectivity program. It has subsumed all the ongoing and proposed broadband network projects. The project is being executed by BSNL, RailTel, and Power Grid and is being funded by the Universal Service Obligation Fund (USOF).

OBJECTIVES:

- It aims to connect all of India's households, specifically rural households through demand, affordable high-speed internet connectivity to fulfill the objectives of the Digital India program in partnership with the states and the private sector.
- The Bharat Net project proposes broadband connectivity to households under village Panchayats and even to government institutions at the district level.
- It intends to cover all 2.5 lakh Gram Panchayats for the provision of E-governance, E-healthcare, E-Commerce, E-Education, and Public Interest Access services.
- The first phase of the Bharat Net project will be completed in December 2017, providing internet access to 1 lakh Gram Panchayats. So far, 83000 Gram Panchayats have been connected.
- The equipment for the program are indigenously designed and are manufactured in India, under the "Make in India" initiative.

Recent Development:

Under Phase -II, implementation is done through the State Model, Private Sector Model, and CPSU Model. Not only will this phase include an optimum mix of channels for connectivity (Optical Fibre Cables, Radio, and Satellites), but will also be providing last-mile connectivity through Wi-Fi or similar technology to ensure that internet is available at the home/office. This is based on the recommendations of the committee on the National Open Fiber Network which submitted its report in 2015.

About eight states have opted for a State-led model while the satellite model is being implemented mostly in states which have a difficult terrain. Uttar Pradesh is implementing the project through both BSNL (CPSU Led) and PPP Model.

As on 06 March 2020, Optical Fiber Cables have been laid for over 4.27 lakh kilometers connecting more than 1.5 Lakh gram panchayats. Around 1.37 lakh of these have been made service ready as per the latest data on BBNL website.

CHAPTER 3: SPACE TECHNOLOGY

3.1 INTRODUCTION

Space programs and activities of India started in early 1960 with the beginning of scientific investigations and experiments of the upper atmosphere and ionosphere using small rockets. These programs were conducted over the magnetic equatorial region passing through THUMBA, in Thiruvananthapuram (Kerala). It was Dr. Vikram Sarabhai who realized the immense potential of the Space program and technology for the country and its development as well as solving the problems and challenges of the common man.

With the establishment of the Indian National Committee for Space Research (INCOSPAR) by the Government of India in 1962, India thought of making an effort to start its space program. ISRO(Indian Space Research Organisation) Superseded INCOSPAR in 1969 under the able leadership of Vikram Sarabhai. The initial thrust and leadership to utilize space research to solve the problem of the common man were started under the visionary leadership of Vikram Sarabhai.ISRO's main objectives were capacity building, self-reliance, to advance the causes of the Space program and research for Nation Building and Development of the people.

INDIAN SPACE RESEARCH ORGANISATION (ISRO):

Formation:

- The Indian National Committee for Space Research (INCOSPAR) was established by Jawaharlal Nehru in 1962 under the Department of Atomic Energy (DAE).
- Eminent scientist Dr. Vikram Sarabhai had a big role in this development. He understood the need for space research and was convinced of the role it can play in helping a nation develop.
- INCOSPAR set up the Thumba Equatorial Rocket Launching Station (TERLS) at Thumba, near Thiruvananthapuram at India’s southern tip. TERLS is a spaceport used to launch rockets.
- The INCOSPAR became ISRO in 1969.
- The Department of Space was created in 1972 and ISRO became a part of it and remains so to date. The Space Department reports directly to the Prime Minister of the country.

About ISRO:

ISRO or Indian Space Research Organisation is India's space agency founded in 1969 to help develop an indigenous Indian space program. It is one of the 6 largest space agencies in the world today. ISRO maintains one of the biggest fleets of remote sensing (IRS) and communication (INSAT) satellites catering to the needs of the nation through a network of centers, offices and research institutes in different parts of the country. ISRO functions in the following areas: broadcasting, weather forecasting, disaster management, geographic information systems, navigation, cartography (maps), tele-medicine, distance education satellites, etc.

ISRO is headquartered in Bengaluru.

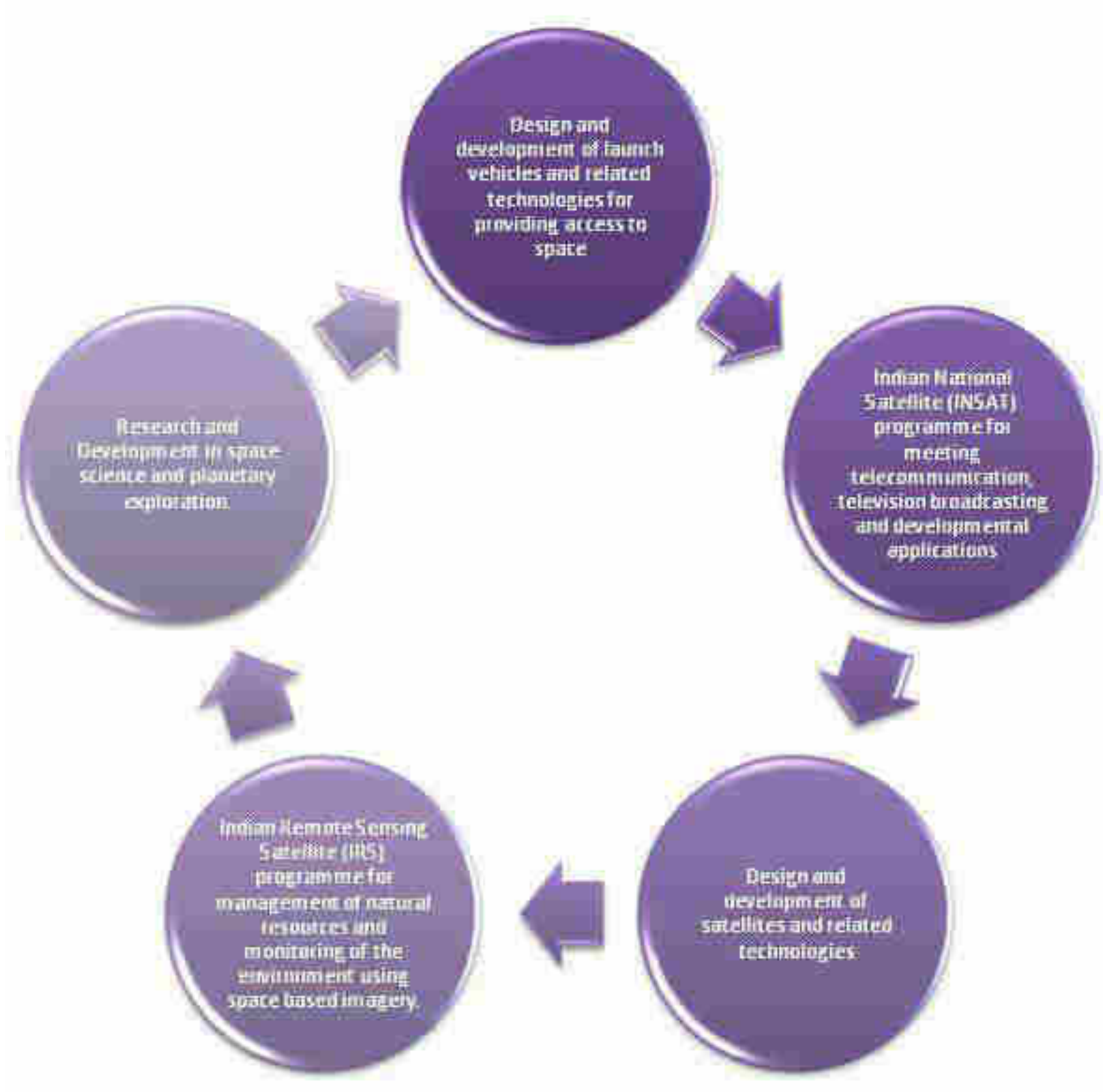
ISRO has many facilities each dedicated to a specialized field of study in space. A few of them are as follows:

- Vikram Sarabhai Space Centre (VSSC), Thiruvananthapuram
- Liquid Propulsion Systems Centre (LPSC), Thiruvananthapuram
- Satish Dhawan Space Centre (SDSC-SHAR), Sriharikota
- Space Applications Centre (SAC), Ahmedabad
- National Remote Sensing Centre (NRSC), Hyderabad

Vision, Mission, and Objectives:

ISRO's vision is stated as "Harness space technology for national development while pursuing space science research and planetary exploration."

ISRO Mission:-



Timelines of ISRO Achievements:

- The first Indian-made satellite was the RH-75 (Rohini-75). It was launched from TERLS in 1967. It was considered a ‘toy rocket’ and weighed just 32 kg.
- ISRO built its first satellite in 1975 and named it Aryabhatta. This was launched by the Soviet Union.
- The first Indian-built launch vehicle was SLV-3 and it was used to launch the Rohini satellite in 1980.
- ISRO launched the first INSAT in 1988. It was a communication satellite.
- ISRO also launched the first IRS (remote-sensing satellite) in 1988.

- ISRO has developed three types of launch vehicles (or rockets) namely, the PSLV (Polar Satellite Launch Vehicle), the GSLV (Geosynchronous Satellite Launch Vehicle) and Geosynchronous Satellite Launch Vehicle Mark III (GSLV Mark III or LVM).
- ISRO launched its first lunar mission Chandrayaan I in 2008.
- It also launched the Mars Orbiter Mission or the Mangalyaan in 2014. With this, India became the first country to achieve success in putting a satellite on Mars orbit in its maiden attempt and the fourth space agency and the first Asian agency to do so.
- In 2017, ISRO created another world record by launching 104 satellites in a single rocket. It launched its heaviest rocket yet, the Geosynchronous Satellite Launch Vehicle-Mark III and placed the GSAT 19 in orbit. There are future plans for a human spaceflight (Gaganyaan), interplanetary probes and a solar mission as well.

3.2 INDIAN NATIONAL SATELLITE SYSTEM (INSAT):

The INSAT series of satellites that were commissioned in the year 1983 have now become one of the most compatible and reliable systems of ISRO. The Indian Remote Sensing Satellite System. The remote sensing satellites are continuously relaying signals and spatial resolutions of various imageries. The Indian Remote Sensing Satellites were commissioned in the year 1998 with launch of IRS-1A.

Indian Space programme has become self-reliant today with the commissioning of two launch vehicles

- **Polar Satellite Launch Vehicle** for launching Indian Remote Sensing Satellite into Polar orbit
- **Geosynchronous Satellite Launch Vehicle** for launching communication satellites into Geosynchronous orbit.

SATELLITES AND APPLICATIONS:

Major applications Of Satellites system of the INSAT CLASSES INCLUDES the following:

Major Applications of INSAT System are:

1. Edusat Programme
2. Gramsat Programme
3. Telemedicine
4. Television
5. Radio Networking
6. Satellite News Gathering And Dissemination
7. Telecommunications
8. Mobile Satellite Services
9. Meteorology
10. Satellite Aided Search And Rescue
11. Satellite Navigation
12. Disaster Management Support (DMS) Programme
13. Village Resource Centres

Fig 3.1: APPLICATIONS OF SATELLITE SYSTEM

(Image source: Byjus)

In the last few decades, the INSAT systems and Satellites Communication Technologies (SATCOM) have been offering several ranges of services ranging from Social and Economic development services which are reliable, seamless and reach the widest possible distances in the remotest corner of the country. Since its initiations the Satellite program of ISRO have covered diverse areas of applications :

- Telecommunications
- Tele-education
- Data Services
- DTH and Cable TV
- Rural areas connectivity
- Village resources
- Disaster management and rescue operations, And many more

Edusat Programme:

EDUSAT', India's first thematic satellite dedicated exclusively for educational services, was used extensively to cater to a wide range of interactive educational delivery modes like a one-way TV broadcast, video conferencing, computer conferencing, web-based instructions, etc. it had many objectives like supplementing the curriculum-based teaching, effective teacher training, providing access to quality resource persons and new technologies, thus finally resulting in taking education to every nook and corner of India. EDUSAT provided connectivity to schools, colleges and higher levels of education and supported non-formal education including development communication.

EDUSAT Programme was implemented in three phases: pilot, semi-operational and operational phases. Pilot projects were conducted during 2004 in Karnataka, Maharashtra and Madhya Pradesh with 300 terminals. The experiences of pilot projects were adopted in semi-operational and operational phases. During the semi-operational phase, almost all the states and major national agencies were covered under the EDUSAT program. The networks were expanded under the operational phase with funding by respective state governments/user agencies.

The EDUSAT (GSAT-3) satellite provided its services till September-2010, supporting Tele-education, Telemedicine and Village Resource Centres (VRC) projects of ISRO. After its decommissioning, the traffic of Tele-education networks was migrated to other ISRO satellites. Most of the tele-education networks operating in Ku-band were migrated from GSAT-3 to INSAT-4CR and those in Ext. C-band networks were migrated to INSAT-3A, INSAT-3C and GSAT-12. The migration of the remaining few networks is in the pipeline.

Gramsat:

Keeping in mind the urgent need to eradicate illiteracy in the rural belt which is necessary for the all-round development of the nation ISRO has come up with the concept of dedicated GRAMSAT satellites.This satellite is carrying six to eight high powered C-band transponders, which can disseminate regional and cultural specific audio-visual programs together with video compression techniques.

The high power in C-band has enabled even remote area viewers outside the reach of the TV transmitters to receive programmers of their choice in a direct reception mode with a simple dish antenna.

The following features are provided by Gramsat Satellite:-

1. Its communications networks are at the state level connecting the state capital to districts, blocks and enabling a reach to villages.
2. Tele-health and telemedicine services
3. It is also providing computer connectivity data broadcasting, TV-broadcasting facilities having applications like e-governance, development information, teleconferencing, helping disaster management
4. Providing rural-education broadcasting.

Telemedicine:

Telemedicine allows health care professionals to evaluate, diagnose and treat patients at a distance using telecommunications technology. The approach has been through a striking evolution in the last decade and it is becoming an increasingly important part of the American healthcare infrastructure.

Telemedicine or Telehealth is the distribution of health-related services and information via electronic information and telecommunication technologies.It allows long-distance patient and clinician contact, care, advice, reminders, education, intervention, monitoring, and remote admissions. Telemedicine is used in a more limited sense to describe remote clinical services, such as diagnosis and monitoring. When rural settings, lack of transport, a lack of mobility, decreased funding, or a lack of staff restricts access to care, telehealth may bridge the gap.

Telehealth includes two or more clinicians discussing a case over video conference;or a robotic surgery occurring through remote access;, live feed and application combinations; tests being forwarded between facilities for interpretation by a higher specialist; physical therapy done via digital monitoring instruments, home monitoring through continuous sending of patient health data; etc.

Agriculture and Soil:

Satellite observations provide Reliable information regarding crop acreages, timely forecasts of production & yields. ISRO has launched two projects namely - National Agricultural Drought Assessment and Management System (NADAMS) and Forecasting Agricultural output using Space, Agrometeorology and Land-based observations (FASAL), respectively.

Water Resources:

Space technology provides comprehensive inputs on surface water, snow cover, groundwater etc. ISRO is actively involved in several projects to make the inventory and monitor the water resources in the country.

Ocean:

Operational oceanography has now become a reality and it relies heavily on ground-based and satellite-based observations. Ocean color observations, Sea Surface Temperature (SST), Wave Height (SWH), ocean chlorophyll, sea ice parameters and ocean surface winds are analyzed using satellite data.

Satellite-based oceanographic observations generate data products on Potential Fishing Zone Advisories, Photosynthetically Active Radiation (PAR), ocean primary production, aerosol optical depth, total suspended sediments, suspended sediment concentration and ocean state forecast. The satellite derived Suspended Sediment Concentration (SSC) maps are essentially used in maintaining the navigational channels, safeguarding marine installations and protection of the vital coastal habitats. The freshwater budget can be derived from Sea Surface Salinity (SSS) and sea ice parameters.

Weather and Climate:

Weather refers to the instantaneous state of the atmosphere and climate is the long term average state of the atmosphere. Weather prediction and climate monitoring require an in-situ observational network of Automatic Weather Stations (AWS), Doppler Weather Radar, Wind Profiler etc., as well as satellite measurements. ISRO has established a network of 1158 Automatic Weather Stations (AWS) across the country.ISRO has developed technology for many of these observing instruments in house. The data from these AWS are used for initializing numerical weather prediction as well as validating the forecasts.

Energy:

India has a clear direction of utilizing renewable energy for meeting the country's requirements. Satellite remote sensing provides synoptic data, covering larger areas continuously for longer periods. Earth Observation data helps analyze Winds, solar and wave energy resources.

Rural Development:

For planning, monitoring and impact assessment viz. Integrated Watershed Management Programme (IWMP), Space-Based Information Support for Decentralized Planning (SISDP), and MGNREGA, Various programs are carried out by ISRO addressing the developmental priorities of the country

Urban Development:

The urban environment of cities faces several challenges such as the rate of population increase, urban sprawl etcThese changes f by way of increased spatial accuracy and frequent revisit periods which allows planners to construct action scenarios and compile the accurate database of spatial environments. information regarding changes in land-use patterns over the past for carrying out various urban planning, planning alternatives and management activities can be obtained through the use of satellite data.

For diverse applications like Television, DTH Broadcasting, VSAT etc. Satellite Communication utilization has become widespread. The technology has matured substantially over the past three decades and is being used on a commercial basis for a large number of applications. Most of us are touched by satellite communication in more ways than we realise.

The potential of the technology for societal applications continues to fascinate ISRO and efforts are on to leverage the benefits of technology to the betterment of mankind. Tele-education, Tele-medicine, Village Resource Centre (VRC) and Disaster Management System (DMS)

Programmes are some important initiatives pursued by ISRO towards societal development. The potential of space technology for applications of national development is enormous.

Disaster Management Services:

ISRO is actively involved in providing space inputs on a near real-time basis for major natural disasters in the country, such as floods, cyclones, landslides, earthquakes and so on. The information on fire alerts (forest fire, stubble burning) are also provided to the concerned. While operational drought assessments are provided by the Mahalanobis National Crop Forecast Centre (MNCFC), necessary R&D products are also undertaken by the National Remote Sensing Centre (NRSC), ISRO. Disaster Support Centre (DSC), NRSC has extended the satellite-based support to Central and State Departments. For example, floods in eight States, viz., Assam, Bihar, Uttar Pradesh, Delhi, Odisha, Mizoram, Tripura have been monitored using satellite data by NRSC, ISRO.

Flood inundation in KERALA was monitored in recent times by NRSC.Apart from regular flood maps, flood persistence map, showing the areas under persistent floods, was also provided to Kerala. ISRO has extended the satellite images based support to central and state government departments in providing near real-time inputs from space on all major disasters in the country During July-August, 2018, . Through the sharing of valuable data, it has helped the MHA, NDMA, NDRF and State Disaster Management Departments. Considering the high intensity of the disasters, an international charter was also activated for obtaining more frequent high-resolution satellite datasets. FOR public use all information related to disaster is disseminated via BHUVAN satellite.

Landslides:

Landslides cause huge damages, particularly along pilgrim routes. ISRO prepared Landslide Hazard Zonation maps for pilgrim routes in Himachal Pradesh, Uttarakhand and Meghalaya.Also, ISRO is preparing seasonal landslide inventory regularly.These satellite-based inputs are very useful for preparedness.

Experimental Landslide Early Warning System for Rainfall Triggered Landslides is carried out for the following routes namely Rishikesh-Badrinath, Rishikesh-Uttarkashi-Gomukh, Chamoli-Ukhimath Rudraprayag-Kedarnath and Pithoragarh-Malpa in Uttarakhand during specific seasons

Near real-time information on landslides is derived regularly during major landslide events in the country and disseminated through Bhuvan geoportal. A real extent of a landslide is also estimated using satellite data and DSMs. Also, in case of river blockade due to landslides, necessary inputs are provided to the Govt. from time to time.

Cyclones:

With a large coastline, India is susceptible for cyclones. It is important to understand the impacts of cyclones, concerning its earlier footprints, low lying areas, etc, wherein satellite images provide such inputs. Using historical satellite data and Digital surface models, these inputs are derived. ISRO uses geo-stationary and low earth orbit satellites for providing experimental inputs on cyclogenesis, cyclone track, cyclone intensity. INSAT series of satellites with frequent imaging provide the cyclone parameters for near real-time analysis.ISRO monitors the formation of cyclones and carries out cyclone track prediction. Besides, near real-time inundation mapping due to cyclones are also prepared.

Earthquakes:

Very high-resolution satellite data is used by ISRO to provide inputs on damage assessment for major earthquake events. During 2015, the Nepal government was supported by ISRO which provided satellite-based inputs on damages done by the earthquake that rocked the area.

3.3 SATELLITE LAUNCH VEHICLES:

A launch vehicle or carrier rocket is a rocket-propelled vehicle used to carry a payload from Earth's surface to space, usually to Earth orbit or beyond. Orbital launch vehicles can be grouped based on many different factors, most notably payload mass, although price points are a major concern for some users. Most launch vehicles have been developed by or for national space programs, with considerable national prestige attached to spaceflight accomplishments. Payloads include crewed spacecraft, satellites, robotic spacecraft, scientific probes, landers, rovers, and many more.

Fig 3.2 ISRO Launch Vehicles Over the Years

(Image source: ISRO.GOV.IN)

Satellite Launch Vehicle -3(SLV-3):

It was successfully launched on July 18, 1980, from Sriharikota Range (SHAR), when Rohini satellite, RS-1, was placed in orbit, thereby making India the sixth member of an exclusive club of space-faring nations. The SLV-3 was India's first experimental satellite launch vehicle, having all solid, four-stage vehicles weighing 17 tonnes with a height of 22m and capable of placing 40 kg class payloads in Low Earth Orbit (LEO)... SLV-3 employed open-loop guidance (with stored pitch program) to steer the vehicle in flight along a predetermined trajectory. The first experimental flight of SLV-3, in 1979, was only a partial success. There were two more launches held in May 1981 and April 1983, Apart from July 1980, orbiting Rohini satellites carrying remote sensing sensors.

The success of the project paved the way for advanced launch vehicle projects such as the Augmented Satellite Launch Vehicle (ASLV), Polar Satellite Launch Vehicle (PSLV) and the Geosynchronous Satellite Launch Vehicle (GSLV).

Augmented Satellite Launch Vehicle (ASLV):

The Augmented Satellite Launch Vehicle (ASLV) Programme was designed to augment the payload capacity to 150 kg, thrice that of SLV-3, for Low Earth Orbits (LEO). While building upon the experience gained from the SLV-3 missions, ASLV proved to be a low-cost intermediate vehicle to demonstrate and validate critical technologies that would be needed for the future launch vehicles like strap-on technology, inertial navigation, bulbous heat shield, vertical integration and closed-loop guidance.

Under the ASLV program four developmental flights were conducted. The first developmental flight took place on March 24, 1987, and the second on July 13, 1988. The third developmental flight, ASLV-D3 was successfully launched on May 20, 1992, when SROSS-C (106 kg) was put into an orbit of 255 x 430 km. ASLV-D4 launched on May 4, 1994, orbited SROSS-C2 weighing 106 kg. It had two payloads, Gamma Ray Burst (GRB) Experiment and Retarding Potential Analyser (RPA) and functioned for seven years.

Polar Satellite Launch Vehicle (PSLV):

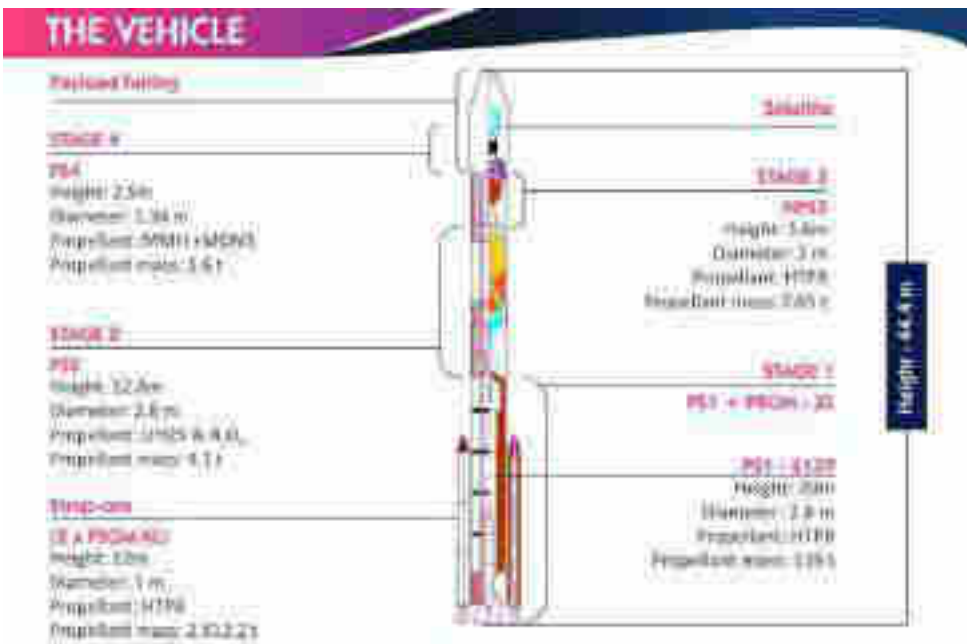
Polar Satellite Launch Vehicle (PSLV) is the third generation launch vehicle of India. It is the first Indian launch vehicle to be equipped with liquid stages. After its first successful launch in October 1994, PSLV emerged as the reliable and versatile workhorse launch vehicle of India with 39 consecutively successful missions by June 2017. During the 1994-2017 period, the vehicle has launched 48 Indian satellites and 209 satellites for customers from abroad.

Besides, the vehicle successfully launched two spacecraft – Chandrayaan-1 in 2008 and Mars Orbiter Spacecraft in 2013 – that later traveled to Moon and Mars respectively.

PSLV earned its title 'the Workhorse of ISRO' through consistently delivering various satellites to Low Earth Orbits, particularly the IRS series of satellites. It can take up to 1,750 kg of payload to Sun-Synchronous Polar Orbits of 600 km altitude.

Due to its unmatched reliability, PSLV has also been used to launch various satellites into Geosynchronous and Geostationary orbits, like satellites from the IRNSS constellation.

- The uppermost stage of PSLV is PS 4, which comprises two Earth storable liquid engines.
- The third stage of PSLV is a solid rocket motor that provides the upper stages of high thrust after the atmospheric phase of the launch.
- PSLV uses an Earth storable liquid rocket engine for its second stage, known as the Vikas engine, developed by Liquid Propulsion Systems Centre.
- PSLV uses the S139 solid rocket motor that is augmented by 6 solid strap-on boosters.
- PSLV uses 6 solid rocket strap-on motors to augment the thrust provided by the first stage in its PSLV-G and PSLV-XL variants. However, strap-ons are not used in the core alone version (PSLV-CA).



<u>Fig 3.3 Polar Satellite Launch Vehicle</u>

(Image source: Spaceflightnow)

<u>Polar Satellite Launch Vehicle -XL:</u>

- It is the upgraded version of PSLV and boosted by more powerful, stretched strap-on boosters with 12-tonne propellant load in its standard configuration

- It Weighs 320 tonne at lift-off and uses larger strap-on motors (PSOM-XL or S12) to achieve higher payload capability. On 29 December 2005, ISRO successfully tested the improved version of the strap-on booster for the PSLV.
- PSLV-XL was first used during the launch of Chandrayaan-1 by PSLV C11. The payload capability for this variant is 1,800 kg to SSO.

Polar Satellite Launch Vehicle -DL:

PSLV-DL variant has only two strap-on boosters with a 12-tonne propellant load on them. PSLV-C44 on 24 January 2019 was the first flight to use the PSLV-DL variant of Polar Satellite Launch Vehicle.

Polar Satellite Launch Vehicle -QL:

PSLV-QL variant has four ground-lit strap-on boosters, each with 12 tonnes of propellant. PSLV-C45 on 1 April 2019 was the first flight of PSLV-QL.

Geosynchronous Satellite Launch Vehicle (GSLV):

Geosynchronous Satellite Launch Vehicle Mark-II (GSLV Mk II) is the largest launch vehicle developed by India, which is currently in operation. This fourth-generation launch vehicle is a three-stage vehicle with four liquid strap-ons. The indigenously developed cryogenic Upper Stage (CUS), which is flight-proven, forms the third stage of GSLV Mk II. From January 2014, the vehicle has achieved four consecutive successes.

GSLV's primary payloads are INSAT class of communication satellites that operate from Geostationary orbits and hence are placed in Geosynchronous Transfer Orbits by GSLV.

Further, GSLV's capability of placing up to 5 tonnes in Low Earth Orbits broadens the scope of payloads from heavy satellites to multiple smaller satellites.

Developed under the Cryogenic Upper Stage Project (CUSP), the CE-7.5 is India's first cryogenic engine, developed by the Liquid Propulsion Systems Centre. CE-7.5 has a staged combustion operating cycle.

One Vikas engine is used in the second stage of GSLV. The stage was derived from the PS2 of PSLV where the Vikas engine has proved its reliability.

The first stage of GSLV was also derived from the PSLV's PS1. The 138-tonne solid rocket motor is augmented by 4 liquid strap-ons.

The four liquid engine strap-ons used in GSLV are heavier derivatives of PSLV's PS2 and use one Vikas engine each.

Geosynchronous Satellite Launch Vehicle Mark III (GSLV MK-III):

GSLV MkIII, chosen to launch Chandrayaan-2 spacecraft, is a three-stage heavy-lift launch vehicle developed by ISRO. The vehicle has two solid strap-ons, a core liquid booster, and a cryogenic upper stage.

GSLV Mk III is designed to carry a 4 ton class of satellites into Geosynchronous Transfer Orbit (GTO) or about 10 tons to Low Earth Orbit (LEO), which is about twice the capability of the GSLV Mk II.

The two strap-on motors of GSLV Mk III are located on either side of its core liquid booster. Designated as 'S200', each carries 205 tons of composite solid propellant and their ignition results in vehicle lift-off. S200s function for 140 seconds. During the strap-ons functioning phase, the two clustered Vikas liquid Engines of L110 liquid core booster will ignite 114 sec after liftoff to further augment the thrust of the vehicle. These two engines continue to function after the separation of the strap-ons at about 140 seconds after liftoff.

On December 18, 2014, The first experimental flight of LVM3 mission lifted off from Sriharikota,and successfully tested the atmospheric phase of flight. In this flight,the Crew module Atmospheric Re-entry Experiment was also carried out. The module re-entered the atmosphere, deployed the parachutes and splashed down in the Bay of Bengal.

On June 05, 2017, GSAT-19 satellite,was placed successfully in Geosynchronous Transfer Orbit (GTO) from SDSC SHAR, Sriharikota by the GSLV-Mk III-D1

GSLV MK III D2, The second developmental flight of GSLV MkIII was successfully launched and carried GSAT-29, a high throughput communication satellite on November 14, 2018 from Satish Dhawan Space Centre SHAR, Sriharikota

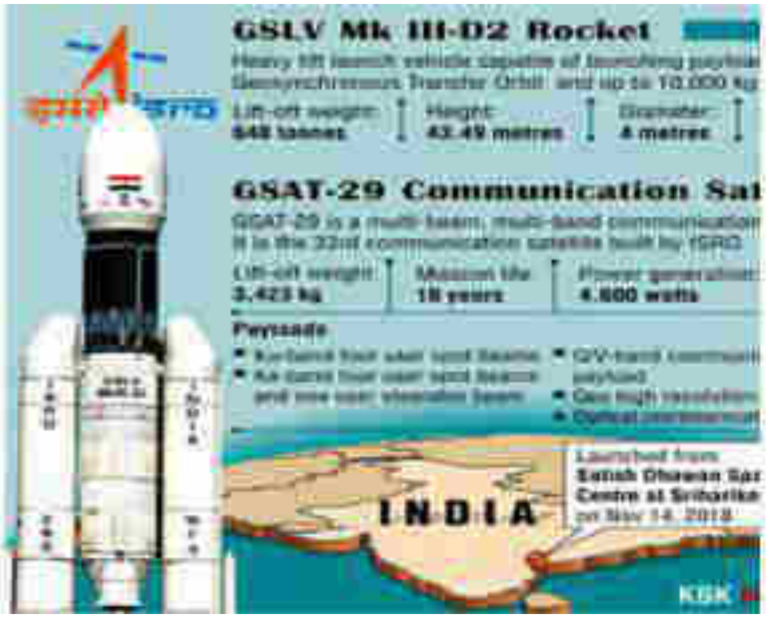


Fig 3.4 GEOSYNCHRONOUS SATELLITE LAUNCH VEHICLE MKIII D-2

(*Image source*: ISRO.GOV.IN)

CHANDRAYAAN 2, India's second Lunar Mission, was successfully placed by GSLV MkIII-M1, into Earth Parking Orbit on July 22, 2019 from Satish Dhawan Space Centre SHAR, Sriharikota.

- The development of GSLV Mk III will facilitate placing the 4 tonne class satellites of the GSAT series into Geosynchronous Transfer Orbits.
- Heavy payloads into Low Earth Orbits of 600 km altitude. Can be placed by The powerful cryogenic stage of GSLV Mk III
- GSLV Mk III uses two S200 solid rocket boosters to provide the huge amount of thrust required for lift off. The S200 was developed at Vikram Sarabhai Space Centre
- The Cryogenic Upper Stage (C25) is powered by CE-20, India's largest cryogenic engine, designed and developed by the Liquid Propulsion Systems Centre.
- The L110 liquid stage is powered by two Vikas engines designed and developed at the Liquid Propulsion Systems Centre.

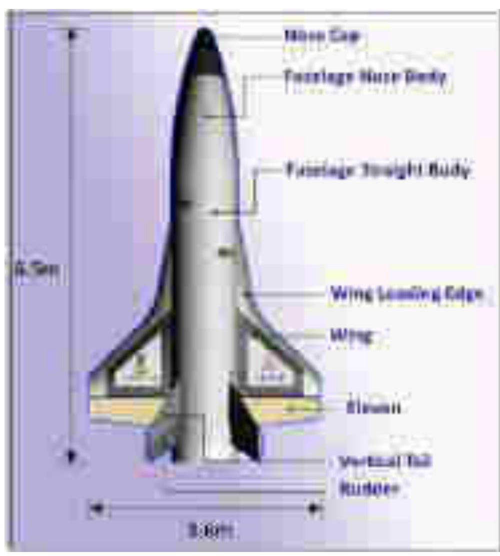
Reusable Launch Vehicle -Technology Demonstrator (RLV-TD):

Reusable Launch Vehicle – Technology Demonstrator (RLV-TD) is one of the most technologically challenging endeavors of ISRO towards developing essential technologies for a fully reusable launch vehicle to enable low cost access to space. The configuration of RLV-TD is similar to that of an aircraft and combines the complexity of both launch vehicles and aircraft.

The winged RLV-TD has been configured to act as a flying test bed to evaluate various technologies, namely, hypersonic flight, autonomous landing and powered cruise flight. In future, this vehicle will be scaled up to become the first stage of India's reusable two stage orbital launch vehicle.

RLV-TD consists of a fuselage (body), a nose cap, double delta wings and twin vertical tails. It also features symmetrically placed active control surfaces called Elevons and Rudder.This technology demonstrator was boosted to Mach no: 5 by a conventional solid booster (HS9) designed for low burn rate.

The selection of materials like special alloys, composites and insulation materials for developing an RLV-TD and the crafting of its parts is very complex and demands highly skilled manpower. Many high technology machinery and test equipment were utilised for building this vehicle.



<u>Fig 3.5 Reusable Launch Vehicle</u>

(Image source: ISRO.GOV.IN)

<u>Objectives of RLV-TD</u>:

- Hypersonic aero thermodynamic characterisation of wing body
- Evaluation of autonomous Navigation, Guidance and Control (NGC) schemes
- Integrated flight management
- Thermal Protection System Evaluation

Achievements:

RLV-TD was successfully flight tested on May 23, 2016 from SDSC SHAR Sriharikota validating the critical technologies such as autonomous navigation, guidance & control, reusable thermal protection system and re-entry mission management.

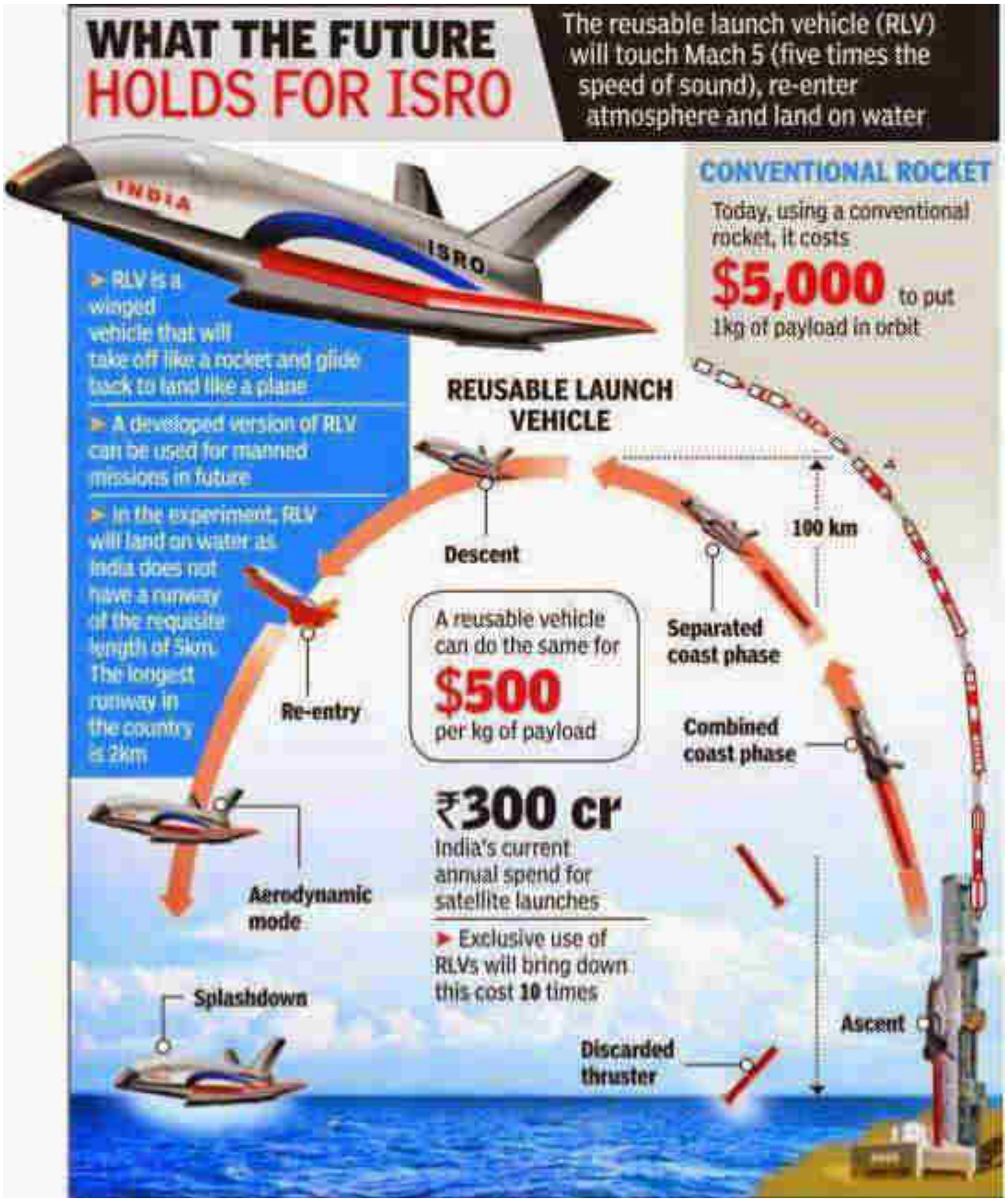


Fig 3.6 Flight Trajectory

(image source: The Hindu)

Scramjet Engine:

The first experimental mission of ISRO's Scramjet Engine towards the realization of an Air Breathing Propulsion System was successfully conducted on August 28, 2016, from Satish Dhawan Space Centre SHAR, Sriharikota.

After a flight of about 300 seconds, the vehicle touched down in the Bay of Bengal, approximately 320 km from Sriharikota. The vehicle was successfully tracked during its flight from the ground stations at Sriharikota. With this flight, critical technologies such as ignition of air-breathing engines at supersonic speed, holding the flame at supersonic speed, air intake mechanism, and fuel injection systems have been successfully demonstrated.

The Scramjet engine designed by ISRO uses Hydrogen as fuel and the Oxygen from the atmospheric air as the oxidizer. This test was the maiden short duration experimental test of ISRO's Scramjet engine with a hypersonic flight at Mach 6. ISRO's Advanced Technology Vehicle (ATV), which is an advanced sounding rocket, was the solid rocket booster used for the test of Scramjet engines at supersonic conditions. ATV carrying Scramjet engines weighed 3277 kg at lift-off.

3.4 INDIAN SATELLITES

From the last four decades, the Indian Space Research Organisation (ISRO) has been involved in several satellite launches beginning with the INSAT satellite systems then gradually progressing towards the launches of **Remote Sensing Satellites** for resource mapping, weather Advisories, disaster management, etc.

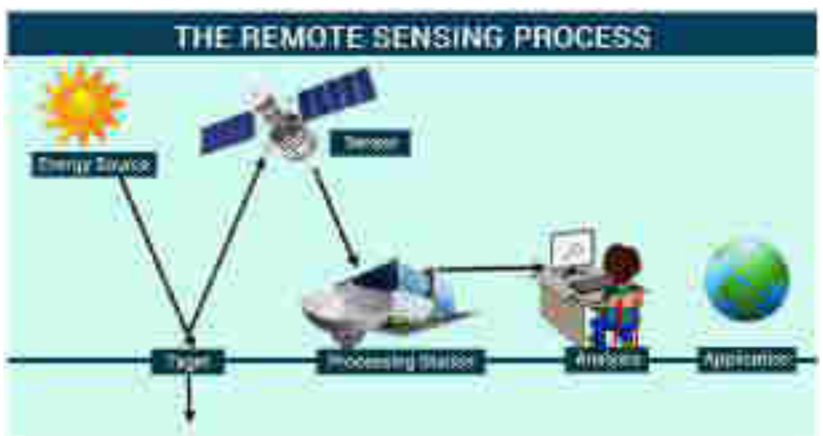
Other systems of Satellites belong to the group of **Geosynchronous** and **Geostationary** satellites.

Remote Sensing Satellite:

This technology is used in numerous fields like geography, hydrology, ecology, oceanography, glaciology, geology to gather information and collect reliable data. GIS (geographical information system) is used for mapping and analyzing feature events on Earth. The statistical analysis and query, with maps, is combined utilized by GIS and remote sensing technology for collecting data and information. The GIS manages information on locations and provides tools for analysis and display of different statistics that include population, economic development, characteristics and vegetation. It also allows linking databases to make dynamic displays. These abilities make GIS different from other systems and make it a wide range of private and public remote sensing applications for planning and predicting outcomes from remote sensing satellites.

There are three essential elements for Remote Sensing:

- A platform to hold the instrument
- A target or object
- An instrument or sensor (to observe the target)



<u>Fig 3.7 Remote Sensing Satellite</u>

(image source: researchgate)

<u>Applications of Remote Sensing Satellites:</u>

in determining soil moisture crop production, Land-use pattern mapping .	To make an inventory of potential landslides	To measure albedo for Earth's radiation budget
The satellites help Measuring sea levels and glacial flow	using thermal remote sensing to monitor active volcanoes	It helps in improving efficiency and safety of air traffic control

To observe the flow of ocean currents and circulation	To further scientific research, It helps in mapping ocean floors.	locating missing aircraft in case of plane accidents.
To map the degradation and loss of wetland ecosystems	Remote sensing satellites are going to make imperishable contribution in further climate change research	military surveillance
precision farming.	To Study geology of earth's surface	It can help in tracking of displaced refugees to help deliver aid and services using satellite imagery.

Category of Remote Sensing Satellite

Polar satellites

Polar satellites are a category of Remote Sensing Satellites that revolve around the earth in a north-south direction as opposed to east-west like the geostationary satellites. They are very useful in applications where the field vision of the entire earth is required in a single day. Since the entire earth moves below them, this can be done easily. They are used in weather applications where predicting weather and climate-based disasters can be done in a short time. They are also used as relay stations.

Geosynchronous Satellite:

When a satellite has an orbital period the same as the Earth's rotation period, it is called a GEOSYNCHRONOUS SATELLITE..the geosynchronous satellite returns to the similar position in the sky after every sidereal day, and during a day, it traces out a path in the sky that is typically some form of the analemma. A geostationary satellite is one special case of geosynchronous satellite, which has a geostationary orbit – a circular geosynchronous orbit directly above the Earth's equator.

Geostationary Satellites:

These satellites are placed into orbit at a distance of around 35,800 km from the earth's surface. They rotate in the same direction as the earth and one revolution of such satellites is the same as one day on earth (roughly 24 hours). This means that, as seen from earth, these satellites will appear to be at the same spot throughout. Hence, the name "geostationary" satellites. These satellites are used as communication satellites and for weather-based applications.

3.5 REMOTE SENSING SATELLITE MISSIONS BY ISRO:

RESOURCESAT-2 :

- RESOURCESAT-2 is a follow-on mission to RESOURCESAT-1 and the eighteenth Remote Sensing satellite built by ISRO.
- RESOURCESAT-2 is intended to continue the remote sensing data services to global users provided by RESOURCESAT-1, and to provide data with enhanced multispectral and spatial coverage as well.

CARTOSAT- SERIES

1. Cartosat -1: CARTOSAT–1 is the first Indian Remote Sensing Satellite capable of providing in-orbit stereo images. The images were used for Cartographic applications meeting the global requirements. Cameras of this satellite have a resolution of 2.5m (can distinguish a small car).

2. Cartosat-2: Cartosat-2 Series Satellite is the primary satellite carried by PSLV-C40. This remote sensing satellite is similar in configuration to earlier satellites in the series and is intended to augment data services to the users.

The imagery sent by satellite will be useful for cartographic applications, urban and rural applications, coastal land use and regulation, utility management like road network monitoring, water distribution, creation of land use maps, change detection to bring out geographical and manmade features and various other Land Information System (LIS) as well as Geographical Information System (GIS) applications.

3. Cartosat-2 A: CARTOSAT – 2A is the thirteenth satellite in the Indian Remote Sensing Satellite series (IRS). Imageries from this satellite were used for cartographic applications like mapping, urban and rural infrastructure development and management, as well as application in Land Information (LIS) and Geographical Information System (GIS).

4. Cartosat-2 B: CARTOSAT - 2B is the seventeenth satellite in the Indian Remote Sensing Satellite series (IRS). CARTOSAT-2B carries a Panchromatic camera (PAN) similar to those of its predecessors - CARTOSAT-2 and 2A.

5. Cartosat-2C: it is an Earth observation satellite that is placed in a sun-synchronous orbit. It is a fifth flight unit of the Cartosat series of satellites. It was built at the space application center Ahmedabad. It was launched on 22 June 2016

6. Cartosat-3: it is a third-generation satellite that is highly advanced and has a high-resolution mapping capability. Under this mission launch,13 Commercial satellites from the USA were also successfully injected into orbit, under commercial arrangement with NewSpace India Limited (NSIL), the commercial arm of ISRO).

Fig 3.8: Cartosat-3

(Image source: ISRO.GOV.IN)

RISAT-2B:

- RISAT-2B is a radar imaging earth observation satellite weighing about 615 kg.
- The satellite is intended to provide services in the field of Agriculture, Forestry and Disaster Management.

Fig 3.9: RISAT-2B

(Image source: ISRO)

In India radar imaging are used for crop estimation because our main crop growing season of kharif is in May-September when it rains and gets cloudy.We have used this data extensively for forestry, soil, land use, geology and during floods and cyclone.Due to an all-weather seeing feature, the satellite becomes special for security forces and disaster relief agencies.

RISAT 2BR1:

India's Polar Satellite Launch Vehicle, in its fiftieth flight (PSLV-C48), successfully launched RISAT-2BR1, an earth observation satellite, along with nine commercial satellites of Israel, Italy, Japan and USA from Satish Dhawan Space Centre (SDSC) SHAR, Sriharikota.

PSLV-C48 was the 75th launch vehicle mission from SDSC SHAR, Sriharikota. This is the 2nd flight of PSLV in 'QL' configuration (with 4 solid strap-on motors).

RISAT-2BR1 is a radar imaging earth observation satellite weighing about 628 kg. The satellite will provide services in the field of Agriculture, Forestry and Disaster Management. The mission life of RISAT-2BR1 is 5 years.

9 Commercial satellites were also successfully injected into designated orbit.

Fig 3.10 RISAT 2BR1

(Image source: Times of India)

3.6 CHANDRAYAAN-1 MISSION

India's maiden lunar probe Chandrayaan-1 (meaning moon craft) was launched by ISRO using a Polar Satellite Launch Vehicle (PSLV).

The probe weighed 1304 kg at launch and 590 kg at lunar orbit. The mission entered into lunar orbit on 8 November 2008. It was orbiting the moon at a distance of 100 km from the lunar surface.

<u>Fig 3.11: Chandrayaan-1</u>

(Image source: Geospatial world)

<u>Objectives of the Mission</u>:

The purpose of the mission was chemical, mineralogical and photo-geologic mapping of the moon	Conducting scientific experiments using instruments on the spacecraft which would yield data for preparing a 3-D atlas of both the near and far sides of the moon; for chemical and mineralogical mapping of the lunar surface at high spatial resolution with particular focus on magnesium, aluminium, silicon, iron, calcium, titanium, uranium, radon and thorium; for increasing scientific

	knowledge; and for testing the impact of a sub-satellite on the moon's surface for future soft-landing missions.
Designing, developing, launching and orbiting a spacecraft around the moon using an Indian-made launch vehicle	Detecting water-ice on the moon

Achievements:

- Chandrayaan-1 carried 11 scientific instruments built in India, the USA, Germany, UK, Sweden and Bulgaria. Five of these instruments were built in India.
- The mission made more than 3400 orbits around the moon.
- The mission sent back to earth 70000 images of the lunar surface. Some of the images had a good resolution of 5 m while many other moon missions provided only a 100 m resolution.
- The mission sent its first image of the entire earth on 25 March 2009. These images were captured by the Terrain Mapping Camera (TMC) which was one of the scientific payloads of the mission.
- The mission also carried a Moon Impact Probe (MIP) whose purpose was to crash land on the lunar surface and send information that would help in preparing a rover to land on the surface in a future mission.
- The MIP was successfully deployed and data received from it confirmed the presence of water on the moon's surface.
- Chandrayaan has confirmed the magma ocean hypothesis which implies that the moon was completely molten once.
- The TMC also captured images of the landing site of the U.S. spacecraft Apollo 15.
- The mission also detected titanium, confirmed the presence of calcium and also acquired the most accurate measurements of iron, aluminum and magnesium on the moon.
- Scientists from ISRO and other participating agencies have termed the mission success with 90% of the stated objectives being seen through.

The estimated project cost was Rs.386 Crore or US$60 million. Although the mission was intended to last for two years, it ended on 28 August 2009 when communications to the probe were lost suddenly. The probe lasted for 312 days or 10 months and 6 days.

3.7 CHANDRAYAAN-2 MISSION

About Mission:

Chandrayaan – 2 is the second lunar mission of India after the success of Chandrayaan 1. This mission was conducted for topographical research and mineralogical studies to have a better understanding of the Moon’s origin and evolution. Chandrayaan 2 Mission was launched from the Satish Dhawan Space on July 22, 2019, by GSLV Mk III. The main aim of Chandrayaan 2 was to trace the location and abundance of lunar water on the moon’s surface.

Fig 3.12 India's Lunar Missions

(Image source: Byjus)

Objectives of Chandrayaan-2:

- Chandrayaan 2 fostered the findings of Chandrayaan 1 as reported by the ISRO.
- The mission will target the "South Polar region" of the Moon which is completely unexplored.
- The mission focused on the extensive mapping of the lunar surface for studying variations in its composition and tracing the Moon's origin and evolution.

- Chandrayaan 2 was considered as a challenging mission as the South Polar Region of the Moon was totally unexplored by any space agency before.

Components of Chandrayaan-2:

Note:- All the parts/components were indigenously developed in India.

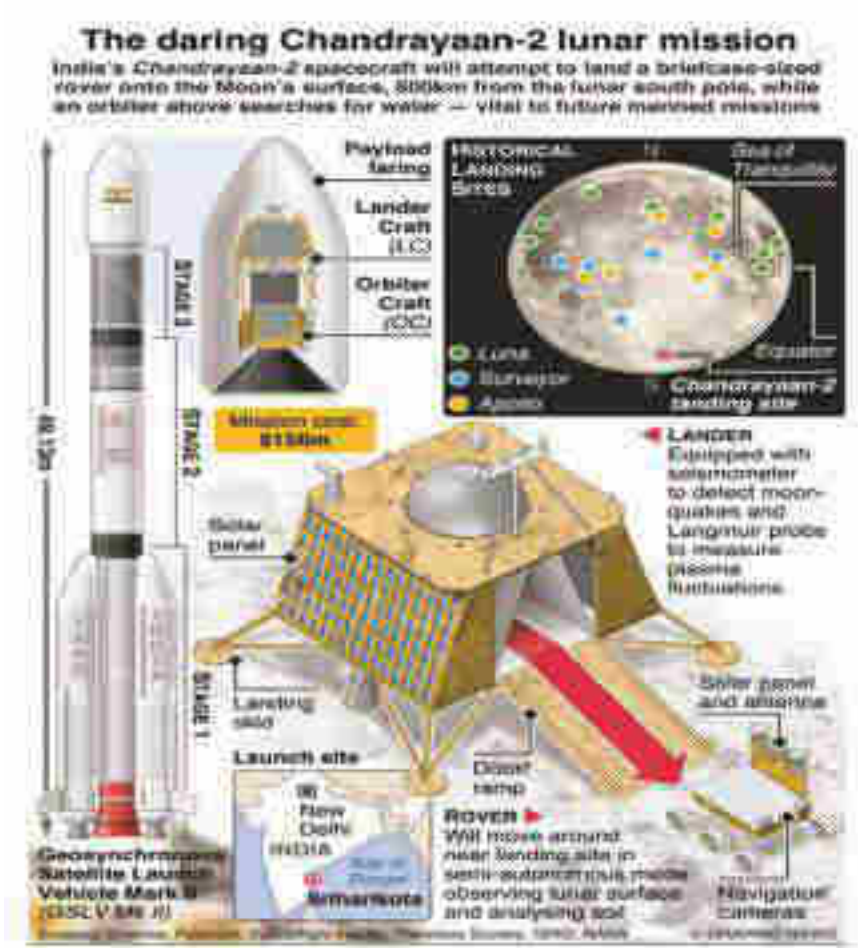


Fig 3.13: Chandrayaan-2 mission features

(image source:THE HINDU)

The orbiter, lander and rover collectively carried 14 scientific payloads, including a Laser RetroReflector Array from NASA that provided precise measurements of the distance between the Moon and the Earth. Chandrayaan-2's orbiter shall continue its mission for around a year.

Significance of The Mission:

- In all the space missions, no country has ever attempted to land a spacecraft in the polar regions of the moon. This gave India a lead in space exploration on an international level.
- Due to the moon's axis, few regions on the South Pole always remain dark, especially the craters and have higher chances of containing water.
- The craters might have never received sunlight because it at very low angles in the Polar Regions and thus, increasing the chances of presence of ice on such surfaces.

- The lunar surface area at the south pole of the Moon that remains in shadow is much larger than the North Pole thus making the moon's South Pole interesting. This also increases the probability of the existence of water in permanently shadowed areas around it.

3.8 MARS ORBITER MISSION (MANGALYAAN)

Mars Orbiter Mission (MOM) or Mission Mangalyaan is the first interplanetary space mission of Indian Space Research Organisation (ISRO). It was successfully launched on 5th November 2013. The space probe of this mission has been orbiting Mars since 24th September 2014.

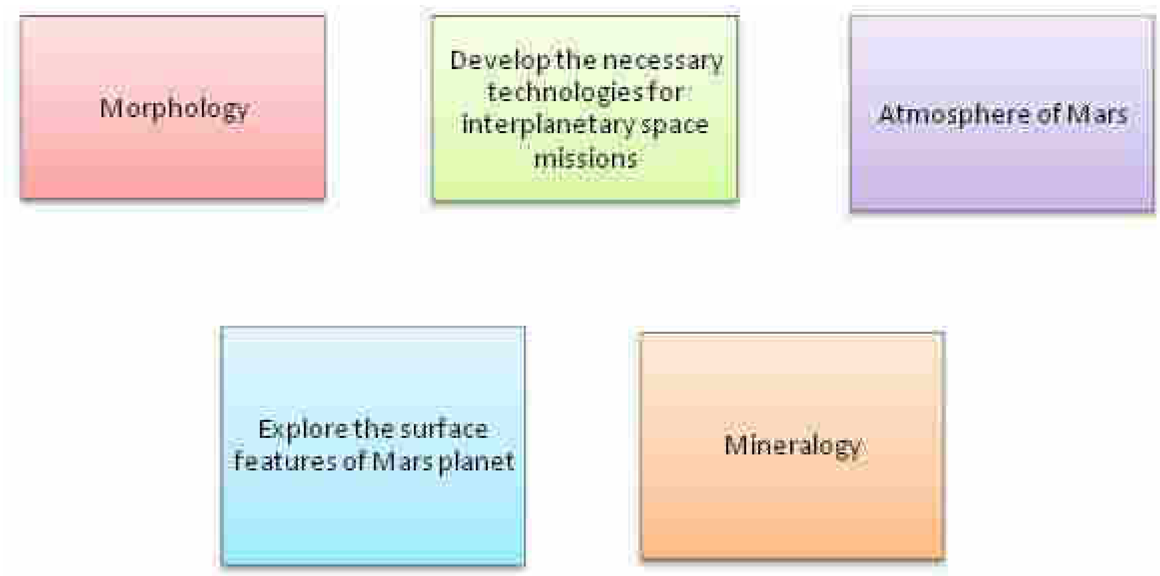
<u>Highlights Of The Mission:</u>

- ISRO is the 4th space agency to reach the orbit of Mars after Roscosmos, NASA, European Space Agency (ESA).
- India is the first nation to reach the orbit of Mars on the very first attempt.
- India is the first Asian country to reach the orbit of Mars.
- Mars Orbiter Mission (MOM) was launched using Polar Satellite Launch Vehicle (PSLV XL – C25) from Satish Dhawan Space Centre, Sriharikota, Nellore District of Andhra Pradesh. It took 298 days for the Mars probe to reach the orbit of Mars. The probe is being tracked from ISRO centres located in Bangalore.

<u>Fig 3.14: Mars Orbiter Mission</u>

(Image source: Americaspace.com)

Objectives Of The Mission:



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Payloads On The Mangalyaan:

The payload in the Mars Orbiter Mission (MOM) was made of 5 scientific instruments:-

- LAP (Lyman-alpha Photometer)
- MSM (Methane Sensor for Mars)
- MENCA (Mars Exospheric Neutral Composition Analyser)
- TIS (Thermal Infrared Imaging Spectrometer)
- MCC (Mars Colour Camera)

3.9 GPS-AIDED GEO-AUGMENTED NAVIGATION (GAGAN)

The GPS-aided GEO augmented navigation (GAGAN) is an implementation of a regional satellite-based augmentation system (SBAS) by the Government of India. The (Airports Authority of India). AAI's efforts towards implementation of operational SBAS can be viewed as the first step towards the introduction of modern Communication, navigation and surveillance/Air Traffic Management system over Indian airspace.

With the help of reference stations, navigation land uplink stations, 3 Indian mission control centers, and installation of all associated software and communication links that have been set up, GAGAN will be able to help pilots to navigate in the Indian airspace by an accuracy of 3 m. hence this will facilitate landing aircraft in marginal weather and difficult approaches

INDIAN REGIONAL NAVIGATION SATELLITE SYSTEM (IRNSS) -NAVIC:-

The Indian Space Research Organisation (ISRO) and its commercial wing ANTRIX developed the Indian Regional Navigation Satellite System or IRNSS with its operational name of NAVIC (Navigation with Indian Constellation). It is a Navigation Satellite System that will provide accurate real-time positioning and timing services over India and the region around the country.

Features Of NAVIC:

- It consists of 7 satellites at an altitude of approximately 36000 km above sea level.
    - 3 are in Geostationary Orbit
    - 4 are in Geosynchronous Orbit

- The objective of the NavIC is to provide navigation, timing and reliable positioning services in and around India.
- Working of the NavIC is very similar to the GPS (Global Positioning System) implemented by the United States.
- The NavIC is certified by 3GPP (3rd Generation Partnership Project) which is responsible for coordinating mobile telephony standards globally.

Objectives:

- It is an independent regional navigational satellite system developed by India.
- It is being designed to give precise position data service to users located in India and also to users in the area out-spreading up to 1500 km from India's boundary.
- The two kinds of services provided by IRNSS will be:
    - Standard Positioning Service (SPS) and
    - Restricted Service (RS).
- The system can offer a position accuracy of more than 20 m within India which is the primary area of service.
- The IRNSS is being constructed by the Indian Space Research Organisation (ISRO) and is wholly under the Indian government's control. The need for such a system of navigation is that the availability of global satellite navigation systems like the GPS is not assured in hostile conditions.

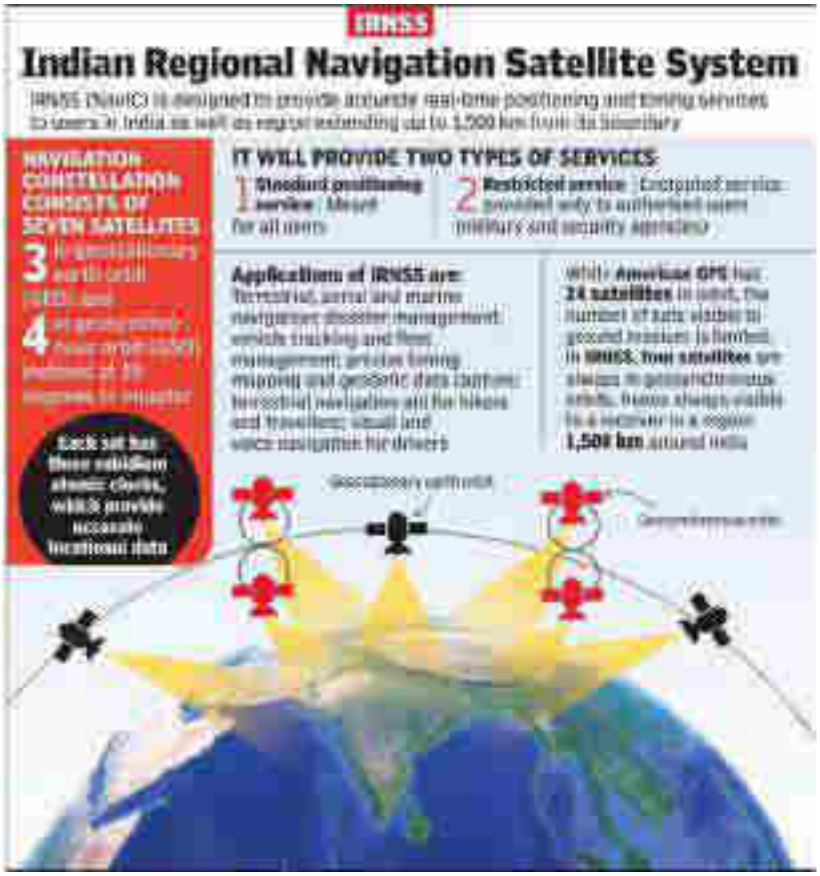


Fig 3.15 Indian Regional Navigation Satellite System

(Image source: Times of India)

There are a few recent developments in the NAVIC (Navigation with Indian Constellation) according to ISRO:

- **The leading semiconductor manufacturer Qualcomm Technologies Inc. developed and tested NavIC-friendly chipsets.**
- **This will help NAVIC support upcoming Automotive, Mobile and IoT applications and platforms.**
- **The collaboration will enable superior location-based services to India's industries and technology ecosystem.**

HYPERSPECTRAL IMAGING SATELLITE (HySYS)

HysYS is an earth observation satellite built around ISRO’s Mini Satellite2 (IMS-2) bus weighing about 380kg. The mission life of the satellite is five years. The primary goal of HysYS is to study the earth’s surface in both the visible, near infrared and shortwave infrared regions of the electromagnetic spectrum.

Highlights:

HySYS carries two payloads:

- Visible Near Infrared (VNIR) with spectral range of 0.4 to 0.95 micrometres with 60 contiguous spectral bands
- Shortwave Infrared Range (SWIR) with spectral range of 0.85 to 2.4 micrometres with a 10 nanometre bandwidth and 256 contiguous spectral bands.
- PSLV-C43 carrying HySYS and 30 secondary payloads was launched on 29 November 2018 from the First Launch Pad of Satish Dhawan Space Centre.
- HySYS was successfully placed in a planned sun-synchronous polar orbit at around 645 km.

Fig 3.16 HySYS

(Image source: Times Of India)

GSAT SERIES SATELLITES

GSAT -6

- GSAT-6 is the twenty fifth geostationary communication satellite of India built by ISRO and twelfth in the GSAT series
- Five of GSAT-6's predecessors were launched by GSLV during 2001, 2003, 2004, 2007 and 2014 respectively
- After its commissioning, GSAT-6 has joined the group of India's other operational geostationary satellites
- GSAT-6 Satellite provides communication through five spot beams in S-band and a national beam in C-band for strategic users
- It was launched using GSLV-D6 (Explained below in GSLV Missions)

GSAT-6A

Fig 3.17: GSAT-6A

(image source:The Hindu)

GSAT -15

GSAT-15, India's latest Communication Satellite is a high power satellite being inducted into the INSAT/GSAT system. Weighing 3164 kg at lift-off, GSAT-15 carried a total of 24 communication transponders in Ku-band, as well as a GPS Aided GEO, Augmented Navigation (GAGAN) payload operating in L1 and L5 bands. GSAT-15 is the third satellite to carry GAGAN payload after GAST-8 and GSAT-10, which are already providing navigation services from orbit. GSAT-15, carried a Ku-band beacon as well to help in accurately pointing ground antennas towards the satellite.

GSAT-15 was launched by Ariane-5 VA-227 launch vehicle from Kourou, French Guiana on the early morning of November 11, 2015

GSAT-16:

- GSAT-16, an advanced communication satellite, weighing 3181.6 kg at lift-off, is being inducted into the INSAT-GSAT system.
- GSAT-16 is configured to carry a total of 48 communication transponders, the largest number of transponders carried by a communication satellite developed by ISRO so far, in normal C-band, upper extended C-band and Ku-band.
- GSAT-16 carried a Ku-band beacon as well to help accurately pointing ground antennas towards the satellite.
- The designed on-orbit operational life of GSAT-16 is 12 years.
- The communication transponders on-board GSAT-16 together ensure continuity of various services currently provided by the INSAT-GSAT system and serve as on-orbit spares to meet contingency requirements or for the augmentation of such services.
- GSAT-16 is launched into a Geosynchronous Transfer Orbit (GTO) by Ariane-5 VA-221 launch vehicle from Kourou, French Guiana. After its injection into GTO, ISRO’s Master Control Facility (MCF) at Hassan took control of the satellite and performed the initial orbit raising maneuvers using the satellite’s on-board Liquid Apogee Motor (LAM), finally placing it in the vicinity of circular Geostationary Orbit.
- After this, the deployment of appendages such as the solar panels, antennas and three-axis stabilization of the satellite was performed.
- GSAT-16 is positioned at 55 deg East longitude in the Geostationary orbit and co-located with GSAT-8, IRNSS-1A and IRNSS-1B satellites.

GSAT 7A:

GSLV-F11 successfully launched GSAT-7A, ISRO's 39th communication satellite, on December 19, 2018, at 1610 hrs (IST) from the Second Launch Pad (SLP) of Satish Dhawan Space Centre SHAR, Sriharikota.

GSLV-F11 is the 13th flight of India's Geosynchronous Satellite Launch Vehicle (GSLV) and its 7th flight with the indigenous Cryogenic Upper Stage (CUS).

GSLV – F11 is ISRO's fourth generation launch vehicle with three stages. The four liquid strap-ons and a solid rocket motor at the core form the first stage. The second stage of the vehicle is equipped with a high thrust engine using liquid fuel. The Cryogenic Upper Stage forms the third and final stage of the vehicle.GSAT-7A

GSAT-7A with a lift-off mass of 2250 kg, is a geostationary satellite carrying communication transponders in Ku-band. The Satellite is built to provide communication capability to the users over the Indian region.

GSAT-9 /SOUTH ASIA SATELLITE

The South Asia Satellite (designated GSAT-9), formerly known as SAARC Satellite, is geostationary communication and meteorology satellite operated by the Indian Space Research Organisation for the South Asian Association for Regional Cooperation (SAARC) region.

The satellite was launched on 5 May 2017.

During the 18th SAARC summit held in Nepal in 2014, Indian Prime Minister Narendra Modi mooted the idea of a satellite serving the needs of SAARC member nations as a part of his neighborhood first policy.

Afghanistan, Bangladesh, Bhutan, Maldives, Nepal and Sri Lanka are the users of the multi-dimensional facilities provided by the satellite.

GSAT-31:

India’s telecommunication satellite, GSAT-31 was successfully launched on February 06, 2019, from Kourou launch base, French Guiana by Ariane-5 VA-247.

GSAT-31 is configured on ISRO’s enhanced I-2K Bus, utilizing the maximum bus capabilities of this type. This satellite will augment the Ku-band transponder capacity in Geostationary Orbit.

Weighing about 2536 kg, GSAT-31 will provide continuity to operational services on some of the in-orbit satellites. The satellite derives its heritage from ISRO’s earlier INSAT/GSAT satellite series. The satellite provides Indian mainland and island coverage.
The designed in-orbit operational life of GSAT-31 is about 15 years.

Fig 3.18 GSAT -31

(Image source:ISRO.GOV.IN)

GSAT -30:

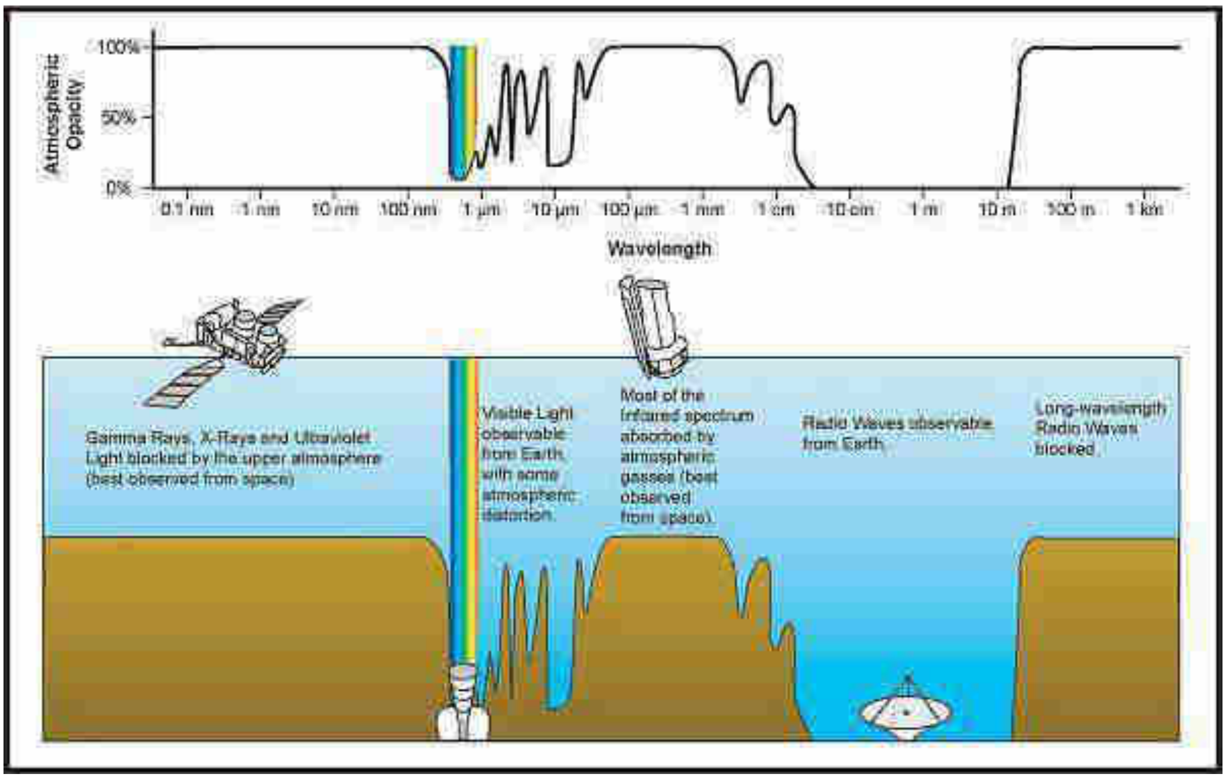
- India's latest communication satellite GSAT-30 was successfully launched from the Spaceport in French Guiana during the early hours today.
- The launch vehicle Ariane 5 VA-251 lifted off from Kourou Launch Base. After a flight lasting 38 minutes 25 seconds, GSAT-30 separated from the Ariane 5 upper stage in an elliptical Geosynchronous Transfer Orbit.
- With a lift-off mass of 3357 kg, GSAT-30 will provide continuity to operational services on some of the in-orbit satellites.
- GSAT-30 derives its heritage from ISRO's earlier INSAT/GSAT satellite series and replaces INSAT-4A in orbit.
- GSAT-30 has a unique configuration of providing flexible frequency segments and flexible coverage.
- The satellite will provide communication services to Indian mainland and islands through Ku-band and wide coverage covering Gulf countries, a large number of Asian countries and Australia through C-band.

Fig 3.19 GSAT -30

(image source:rediff.com)

ASTROSAT MISSION

- Astrosat satellite is a dedicated mission of ISRO on Astronomy.
- It is a mission to observe the celestial sources simultaneously in X-Ray, Optical and UV Spectral bands simultaneously.
- Astrosat satellite was launched from Sriharikota, Andhra Pradesh. The launch centre is named as Satish Dhawan Space Centre (SDSC) or Sriharikota Range (SHAR). The satellite was launched on September 28, 2015, using the launch vehicle Polar Satellite Launch Vehicle (PSLV) C-30.
- The satellite was placed into an orbit of 650 Km. The mission was planned for a period of 5 years.



(*Image source: the wire)*

GROUND FACILITIES OF ISRO :-

Launch Facility:

Satish Dhawan Space Centre (SDSC) or Sriharikota Range (SHAR) is a rocket launch center operated by the Indian Space Research Organisation (ISRO). It is located in Sriharikota in

Andhra Pradesh. Sriharikota Range was renamed in 2002 after ISRO's former chairman Satish Dhawan.

The SLV launchpad:
It was used by the Satellite Launch Vehicle and Augmented Satellite Launch Vehicle is located at the southern tip of the current launch site.

First Launch Pad:
The modern First Launch Pad was built in the early 1990s for the Polar Satellite Launch Vehicle. It has also been used by the Geosynchronous Satellite Launch Vehicle. The First Launch Pad is undergoing major expansion with PIF (PSLV Integration Facilities) project worth 475 crores. Once complete, the First Launch Pad is expected to cater to around 15 launches per year.

Second LaunchPad:
Second Launch Complex became operational in 2005 and unlike First Launch Pad operates on the philosophy of Integrate Transfer & Launch. SLP is configured as a universal launch pad capable of accommodating PSLV, GSLV and GSLV Mk III launch vehicles of ISRO.

Tracking Facilities:

ISRO Telemetry, Tracking and Command Network (ISTRAC), Bengaluru is entrusted with the major responsibility to provide tracking support for all the satellite and launch vehicle missions of ISRO. The major objectives of the centre are: carrying out mission operations of all operational remote sensing and scientific satellites, providing Telemetry, Tracking and Command (TTC) services from launch vehicle lift-off till injection of the satellite into orbit and to estimate its preliminary orbit in space and hardware and software developmental activities that enhance the capabilities of ISTRAC for providing flawless TTC and Mission Operations services. Towards these objectives, ISTRAC has established a network of ground stations at Bengaluru, Lucknow, Mauritius, Sriharikota, Port Blair, Thiruvananthapuram, Brunei, Biak (Indonesia) and the Deep Space Network Stations.

In keeping with its long-established TTC support responsibility, ISTRAC has also been mandated to provide space operations support for Deep Space Missions of ISRO, undertake the development of radar systems for launch vehicle tracking and meteorological applications, establish and operationalize the ground segment for Indian Regional Navigational Satellite System, provide Search & Rescue and Disaster Management Services and support space-based services like telemedicine, Village Resource Centre (VRC) and tele-education.

Data Reception and Dissemination:

National Remote Sensing Centre (NRSC) at Hyderabad is responsible for remote sensing satellite data acquisition and processing, data dissemination, aerial remote sensing and decision support for disaster management. NRSC has a data reception station at Shadnagar near Hyderabad for acquiring data from Indian remote sensing satellites as well as others.

NRSC Ground station at Shadnagar acquires Earth Observation data from Indian remote-sensing satellites as well as from different foreign satellites. NRSC is also engaged in executing remote sensing application projects in collaboration with the users. The Aerial Services and Digital Mapping (ASDM) Area provides end-to-end Aerial Remote Sensing services and value-added solutions for various large scale applications like aerial photography and digital mapping, infrastructure planning, scanner surveys, aeromagnetic surveys, large scale base map, topographic and cadastral level mapping, etc.

Regional Remote Sensing Centres (RRSCs) support various remote sensing tasks specific to their regions as well as at the national level.

National Natural Resources Management System (NNRMS):

National Natural Resources Management System is an integrated natural resource management system of India which aggregates the data about natural resources from the remote sensing satellites and other conventional techniques. NNRMS activities are coordinated at the National level by the Planning Committee of NNRMS (PC-NNRMS) which frames guidelines for implementation of the systems and oversees the progress of remote sensing applications for natural resources management in the country.

ISRO CENTRES :-

Vikram Sarabhai Space Centre (VSSC):

Vikram Sarabhai Space Centre (VSSC) at Thiruvananthapuram is the major centre of ISRO, where the design and development activities of satellite launch vehicles and sounding rockets are carried out and made ready for launch operations. The centre pursues research and development activities for associated technologies such as launch vehicle design, propellants, solid propulsion technology, aerodynamics, aero structural and aerothermal aspects, avionics, polymers and composites, guidance, control, and simulation, computer and information, mechanical engineering, aerospace mechanisms, vehicle integration and testing, space ordnance, chemicals and materials.

The Space Physics Laboratory at VSSC carries out research and studies in atmospheric science and other related space science activities. Ammonium Perchlorate Experimental Plant (APEP) at Aluva in Kerala is a part of VSSC.

The major programmes at VSSC include launch vehicle projects of Polar Satellite Launch Vehicles (PSLV), Geosynchronous Satellite Launch Vehicles (GSLV Mark II and Mark III), Rohini Sounding Rockets, Space-capsule Recovery Experiments, Reusable Launch Vehicles and Air Breathing Propulsion for Advanced Reusable Launch Vehicles.

UR Rao Satellite Centre:

U R Rao Satellite Centre (URSC), Bengaluru, formerly known as ISRO Satellite Centre (ISAC) is the lead centre for building satellites and developing associated satellite technologies. These spacecraft are used for providing applications to various users in the area of Communication, Navigation, Meteorology, Remote Sensing, Space Science and interplanetary explorations. The Centre is also pursuing advanced technologies for future missions. URSC is housed with state-of-the-art facilities for building satellites on an end-to-end basis.

URSC has a unit called Laboratory for Electro-Optics System (LEOS), which is situated in Peenya, Bengaluru and is mainly responsible for research, development and productionisation of Sensors for ISRO programmes. Since inception, URSC has the distinction of building more than

100 satellites for various applications like scientific, communication, Navigation and remote sensing.

Satish Dhawan Space Centre:

Satish Dhawan Space Centre (SDSC) SHAR, Sriharikota, the Spaceport of India, is responsible for providing Launch Base Infrastructure for the Indian Space Programme. This Centre has the facilities for solid propellant processing, static testing of solid motors, launch vehicle integration and launch operations, range operations comprising telemetry, tracking and command network and mission control centre.

The Centre has two launch pads from where the rocket launching operations of PSLV and GSLV are carried out. The centre also provides the necessary launch base infrastructure for sounding rockets of ISRO and assembly, integration and launch of sounding rockets and payloads.

Liquid Propulsion Systems Centre (LPSC):

Liquid Propulsion Systems Centre (LPSC) is the centre for design, development and realization of liquid propulsion stages for ISRO's Launch Vehicles. Development of fluid control valves, transducers, propellant management devices for vacuum conditions and other key components of liquid propulsion systems are also under the purview of this centre. LPSC activities and facilities are spread across its two campuses namely, LPSC, Valiamala, Thiruvananthapuram and LPSC, Bengaluru, Karnataka.

Master Control Facility:

Master Control Facility (MCF) at Hassan in Karnataka and Bhopal in Madhya Pradesh monitors and controls all the Geostationary / Geosynchronous satellites of ISRO, namely, INSAT, GSAT, Kalpana and IRNSS series of satellites. MCF is responsible for the Orbit Raising of satellites, In-orbit payload testing, and On-orbit operations all through the life of these satellites. MCF activities include round-the-clock Tracking, Telemetry & Commanding (TT&C) operations, and special operations like Eclipse management, Station-keeping maneuvers and recovery actions in case of contingencies. MCF interacts with User Agencies for effective utilisation of the satellite payloads and to minimize the service disturbances during special operations.

ISRO Propulsion Centre:

ISRO Propulsion Complex (IPRC), Mahendragiri is equipped with the state-of-the-art facilities necessary for realising the cutting edge propulsion technology products for the Indian space programme. Formerly, IPRC was known as LPSC, Mahendragiri and taking cognizance of the future growth of the space program of our nation and the concomitant expansion at Mahendragiri, it was elevated as IPRC with effect from February 01, 2014.

The activities carried out at IPRC, Mahendragiri are: assembly, integration and testing of earth storable propellant engines, cryogenic engines and stages for launch vehicles; high altitude testing of upper-stage engines and spacecraft thrusters as well as testing of its subsystems; production and supply of cryogenic propellants for Indian cryogenic rocket programme, etc. A Semi-cryogenic Cold Flow Test facility (SCFT) has been established at IPRC, Mahendragiri for the development, qualification and acceptance testing of semi cryogenic engine subsystems.

IPRC is responsible for the supply of Storable Liquid Propellants for ISRO's launch vehicles and satellite programmes.

ISRO Inertial System Unit(IISU):

ISRO Inertial Systems Unit (IISU), Thiruvananthapuram is responsible for the design and development of Inertial Systems for Launch Vehicles and Spacecraft programmes of ISRO. Major systems like Inertial Navigation Systems based on mechanical gyros and optical gyros, Attitude Reference Systems, Rate Gyro Packages and Accelerometer Packages are developed indigenously and used in various missions of ISRO. IISU also designs and develops Actuators and Mechanisms for spacecraft and allied applications.

IISU is engaged in continuous research and Development too.

Indian Institute of Remote Sensing (IIRS):

Indian Institute of Remote Sensing (IIRS) at Dehradun is a premier institute with the objective of capacity building in Remote Sensing and Geo-informatics and their applications through education and training programmes at the postgraduate level. The Institute also hosts and provides support to the Centre for Space Science and Technology Education in Asia and the Pacific (CSSTE-AP), affiliated to the United Nations.

ANTRIX Corporation Limited:

Antrix Corporation Limited (ACL), Bengaluru is a wholly-owned Government of India Company under the administrative control of the Department of Space. Antrix Corporation Limited was incorporated as a private limited company owned by the Government of India in September 1992 as a Marketing arm of ISRO for promotion and commercial exploitation of space products, technical consultancy services and transfer of technologies developed by ISRO. Another major objective is to facilitate the development of space-related industrial capabilities in India.

As the commercial and marketing arm of ISRO, Antrix is engaged in providing Space products and services to international customers worldwide. With fully equipped state-of-the-art facilities, Antrix provides an end-to-end solution for many of the space products, ranging from supply of hardware and software including simple subsystems to a complex spacecraft, for varied applications covering communications, earth observation and scientific missions; space-related services including remote sensing data service, Transponder lease service; Launch services through the operational launch vehicles (PSLV and GSLV); Mission support services; and a host of consultancy and training services.

New Space India Limited (NSIL):

New Space India Limited (NSIL), incorporated on 6 March 2019 (under the Companies Act, 2013) is a wholly-owned Government of India company, under the administrative control of the Department of Space (DOS).NSIL is the commercial arm of the Indian Space Research Organisation (ISRO) with the primary responsibility of enabling Indian industries to take up high technology space-related activities and is also responsible for the promotion and commercial exploitation of the products and services emanating from the Indian space programme. To satisfy the needs of its customers, NAIL draws upon the proven heritage of the Indian Space Program and ISRO's vast experience in diverse branches of Space Technology.

The major business areas of NAIL include:

- Production of Polar Satellite Launch Vehicle (PSLV) and Small Satellite Launch Vehicle (SSLV) through industry;
- Production and marketing of space-based services, including launch services and space-based applications like transponder leasing, remote sensing and mission support services;
- The building of Satellites (both Communication and Earth Observation) as per user requirements.
- Transfer of technology developed by ISRO centres/ units and constituent institutions of Dept. of Space;
- Marketing spin-off technologies and products/ services emanating out of ISRO activities
- Consultancy services.

Northeast Space Application centre:

North Eastern-Space Applications Centre (NE-SAC), located at Shillong, is a joint initiative of DOS and North Eastern Council (NEC) to provide developmental support to the North Eastern Region (NER) using space science and technology. The centre has the mandate to develop high technology infrastructure support to play the catalytic role in the holistic development of NER of India by providing space science and technology support.

The centre also coordinates with the State Remote Sensing Application Centres of NER and acts as a nodal centre for implementation of major national and regional programmes on natural resource management, infrastructure planning, healthcare, education, emergency communication, early warnings for disaster management support and atmospheric science research.

MISCELLANEOUS:

3.10 PLANNED MISSIONS OF ISRO

GAGANYAAN:

- In 2018, India's first manned space mission was announced by Prime Minister Narendra Modi in his Independence Day speech.

- Gaganyaan will be the Indian crewed orbital spacecraft intended to be the basis of the Indian Human Space Flight Program.
- With Gaganyaan, India will become only the 4th country after Russia, the USA and China to send humans to space.
- It will be ISRO's next big project after the anticipated soft landing of Chandrayaan 2 on the lunar
- The target is to launch it before the 75-year celebration of India's independence.
- Before the manned mission scheduled for December 2021, two unmanned tests will be carried out in December 2020 and July 2021.
- ISRO's indigenous mission will be assisted by a few other countries in selecting and training astronauts.
- According to ISRO, a budget of Rs 10,000 Cr. has been set aside for putting the infrastructure in place.
- It is described as a national mission rather than an ISRO mission.

Spacecraft:

- The spacecraft will take 3 Indian astronauts, who will be known as 'vyomanauts' (in Sanskrit 'vyom' means space.
- It will circle the earth for 7 days from a distance of 300-400 km.
- It will be launched by India's biggest rocket GSLV Mk 3 from Sriharikota.
- The 7-ton spacecraft will orbit the earth at an altitude of 400km for up to 7 days.
- ISRO has developed most of the critical technology needed for the mission.
- Its service module will be powered by two liquid-propellant engines.
- It will have life support and environmental control systems.
- It will be smaller than the current Russian and Chinese ones or NASA's Apollo or the planned Orion
- But it will be slightly larger than the U.S Gemini
- ISRO Telemetry Tracking and Command Centre in Peenya will monitor it round the clock.

Crew Module:

- The crew module is a twin-walled sealed structure that recreates earth-like conditions.

- It will be equipped with an Emergency Mission Abort and Emergency Escape System.
- The crew escape system is an emergency system to help the crew pull away from the launch vehicle when the mission has to be aborted. It can be done at the 1st and 2nd stages of the rocket.
- Crew escape system ensures that the crew module gets warning if anything goes wrong with the rocket.
- It pulls the crew module away to a safe distance and can be landed either on sea or land with parachutes.

Fig 3.20 Gaganyaan

(image source:times of india)

ADITYA MISSION

Aditya L-1 Mission is India’s first solar mission planned by the Indian Space Research Organisation (ISRO). Earlier the name was Aditya -1, which has been renamed as Aditya L-1 Mission.

Payloads	Science/Capability
Visible Emission Line Coronagraph (VELC)	Corona/ Imaging , Spectroscopy & Spectopolarimetry (1.05 – 3.0 Solar radii)
Solar Ultraviolet Imaging Telescope (SUIT)	Photosphere and Chromosphere/ Imaging (200-400 nm)
Aditya Solar wind Particle Experiment (ASPEX)	Solar wind/ Particle Analyzer/ spectrometer (H, α, ions 0.1 keV – 5 MeV)
Plasma Analyser Package For Aditya (PAPA)	Solar wind/ In-situ measurement (Ions 0.01 – 25 keV, Ele 0.01 – 3 kev)
Solar Low Energy X-ray Spectrometer (SoLEXS)	Soft X-ray/ spectrometer (1 – 30 keV)
High Energy L1 Orbiting X-ray Spectrometer (HEL1OS)	Hard X-ray/ spectrometer (10 -150 keV)
Advanced Triaxial High Resolution Digital Magnetometers	Measure Magnetic Field/ In-situ measurement (Range: ± 256 nT Accu 0.5 nT)

Fig 3.21 Mission Components

(Image source: ISRO)

Objectives:

- The objective of the Aditya L-1 mission is to study Sun's Corona, Chromosphere and Photosphere.
- Besides, it will study the particle flux emanating from Sun, and the variation of magnetic field strength
- The Aditya-1 mission was planned for observing only the Corona of Sun. The reason behind Corona getting heated to very high temperatures is still a mystery in Solar Physics.
- Aditya -1 mission involved placing the satellite in 800 Km low earth orbit.
- Later ISRO planned to place the satellite in the halo orbit around the Lagrangian Point (L1). L1 is 1.5 Million Km from the Earth. This point provides the advantage of

observing the Sun continuously without any disturbance. Hence the mission was renamed as Aditya L-1 mission.

The satellite will be launched by the PSLV-XL launch vehicle from Sriharikota.

LUNAR POLAR EXPLORATION PROBE:

- It is a robotic lunar mission concept by Indian Space Research Organisation (ISRO) in partnership with Japan Aerospace Exploration Agency (JAXA)
- The purpose of this mission would be to send a lunar rover and land for exploring the South Pole region of the Moon by 2024.
- while ISRO would be responsible for the lander, JAXA is likely to provide the under-development H3 launch vehicle and the rover

Objectives of Mission:

- It would demonstrate new surface exploration technologies related to vehicular transport and lunar night survival for sustainable lunar exploration in polar regions
- For precision landing, it would utilize feature matching algorithm and navigational equipment derived from JAXA
- The lander's payload capacity would be nearly 500 kg including 350 kg rover.
- The rover would carry multiple instruments by JAXA and ISRO including a drill to collect sub-surface samples from 1.5 m depth.
- Water prospecting and analysis are likely to be mission objectives.
- Payload proposals from other space agencies might be sought.

NISAR (NASA-ISRO Synthetic Aperture Radar) MISSION:

NISAR mission is a joint project between NASA and ISRO to co-develop and launch a dual frequency synthetic aperture radar satellite.

It is slated to be launched in 2020-21.

Objectives:

- Measure the changes on earth’s land surface, ice surface, glaciers, earthquakes and volcanoes.
- Find the causes and consequences of such changes.

- NISAR will be the first satellite mission to use two different radar frequencies (L-band and S-band). Hence it can capture resolution even less than a centimeter of earth's surface.
- The L-band SAR is being developed by JPL/NASA, while ISRO is developing S-band SAR.
- The data obtained from the NISAR mission is not meant for building climate resilience.

Significance:

- Understanding climate change
- Predicting natural disasters in advance.
- The L & S-band microwave data obtained from this satellite will be useful for a variety of application, which includes natural resources mapping & monitoring; estimating agricultural biomass over the full duration of crop cycle; assessing soil moisture; monitoring of floods and oil slicks; coastal erosion, coastline changes & variation of winds in coastal waters; assessment of mangroves; surface deformation studies, ice sheet collapses & dynamics, etc.

However, the data acquired from this mission will be useful in developing certain applications, which include –

- identifying crevasses in the glaciers hidden by fresh snow, where human movement takes place,
- identifying the snowpack parameters as an input in Avalanche forecasts,
- studying Glacial Lake Outburst Floods (GLOF) hazards, and
- Identifying inundated areas due to floods/ cyclones. These applications could help in taking measures to minimize the loss of human lives.

MANGALYAAN -2:

- Mangalyaan-2 or the MARS ORBITER ROVER MISSION 2 is India's second interplanetary mission planned for launch to Mars by the Indian Space Research Organisation (ISRO).

- EARLIER the mission was to only carry an orbiter but it will now also carry a lander and a rover.

SHUKRAYAAN -1:

Shukraya 1-1is a proposed orbiter to Venus by the Indian Space Research Organisation (ISRO) to study the surface and atmosphere of Venus.

Objectives:

The mission will enter the atmosphere of Venus and conduct the following researches;

- surface/subsurface studies;
- It will Study of the composition of the atmosphere, its chemistry and their dynamics, and
- It will also analyze the atmospheric interaction of Venus with solar radiation and solar wind.

SPACE TECHNOLOGY-RELATED DEVELOPMENTS

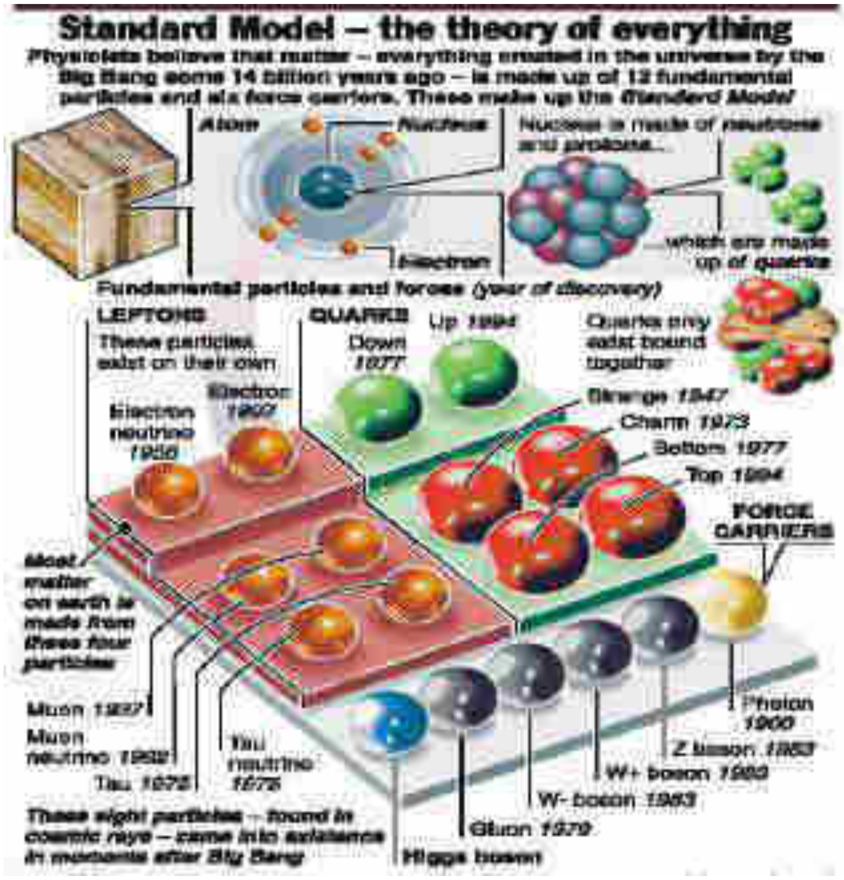
HIGGS BOSON:

Scientists at the European Organization for Nuclear Research (CERN) discovered a new Subatomic particle called HIGGS BOSON or God's Particle in the year 2012.

This discovery had opened several vistas in the arena of Space Technology research and understanding of the dark matter.

The discovery validated the Standard Model of physics, which also predicts that about 60% of the time a Higgs boson will decay to a pair of bottom quarks. In the 1960s Peter Higgs was the first person to suggest that this particle might exist. The Standard Model of particle physics is the theory that describes three of the four known fundamental forces (the electromagnetic, weak, and strong interactions, and not including the gravitational force) in the universe, as well as classifies all known elementary particles.

Scientists do not yet know how to combine gravity with the Standard Model. The Higgs particle is a boson. Bosons are thought to be particles that are responsible for all physical forces. Other known bosons are the photon, the W and Z bosons, and the gluon.



(Image source: CERN)

<u>GRAVITATIONAL WAVE OBSERVATORY IN INDIA</u>

LIGO stands for Laser Interferometer Gravitational-Wave Observatory. It is a large-scale Physics experiment carried out to detect Gravitational waves. LIGO-India is a planned Gravitational-Wave Observatory that will be located in India as part of the worldwide network. This project will be a collaboration between Ligo-USA, India, Germany, Australia and UK LIGO project operates three gravitational wave detectors. 2 of them are located at Hanford in Washington, USA and the other at Livingston in Louisiana, USA. Currently, all three detectors are undergoing upgradation, and the plan is to shift one of the gravitational wave detectors from Hanford to India.

It is a collaboration between LIGO Laboratory and three other institutions which are given below.

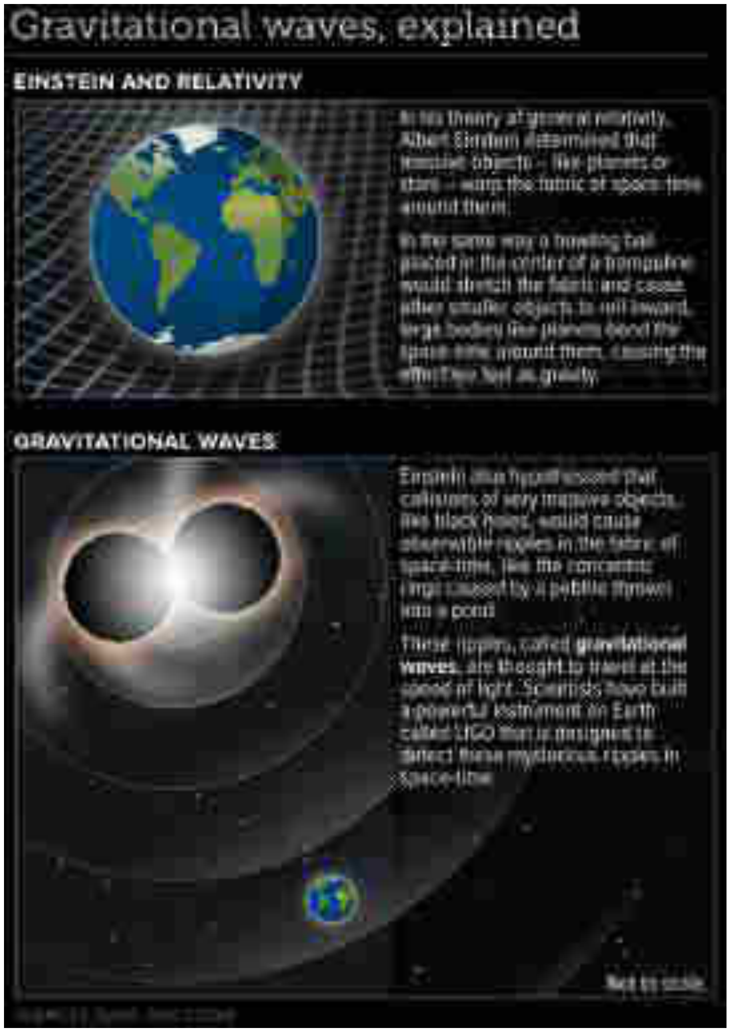
- Institute of Plasma Research (IPR), Gandhinagar.
- Inter-University Centre for Astronomy and Astrophysics (IUCAA), Pune.
- Raja Ramanna Centre for Advanced Technology (RRCAT), Indore.
- The Indian Ligo Observatory project will be connected to Ligo observatories in the USA and Virgo in Italy.

India’s Laser Interferometer Gravitational-Wave Observatory (LIGO) will be set up at AundhaNagnath, Hingoli District in Maharashtra.

About Gravitational Waves:

Gravitational waves are 'ripples' in the fabric of spacetime caused by some of the most violent and energetic processes in the universe.When an object accelerates, it creates ripples in spacetime, just like a boat causes ripples in a pond.These spacetime ripples are gravitational waves. They are extremely weak, so they are very difficult to detect.Two objects orbiting each other in a planar orbit such as a planet orbiting the Sun or a binary star system or the merging of two black holes will radiate Gravitational waves.

Albert Einstein predicted the existence of gravitational waves in 1916 in his general theory of relativity.Einstein's mathematics showed that massive accelerating objects (such as neutron stars or black holes orbiting each other) would disrupt spacetime in such a way that 'waves' of distorted space would radiate from the source.Furthermore, these ripples would travel at the speed of light through the universe.G- Waves can pass through any intervening matter without being scattered significantly.While light from distant stars may be blocked out by interstellar dust, gravitational waves will pass through essentially unimpeded. This feature allows G-Waves to carry information about astronomical phenomena never before observed by humans.Colliding black holes send ripples through spacetime that can be detected on Earth. The Advanced Laser Interferometer Gravitational-Wave Observatory, or Advanced LIGO, which has detectors in Louisiana and Washington, has directly observed these gravitational waves.



Gravitational waves

(image source:Down to Earth)

OUTER SPACE TREATY

- The Outer Space Treaty, formally the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, is a treaty that forms the basis of international space law.
- The treaty was opened for signature in the United States, the United Kingdom, and the Soviet Union on 27 January 1967, and entered into force on 10 October 1967.
- As of June 2019, 109 countries are parties to the treaty, while another 23 have signed the treaty but have not completed ratification.

- Besides, Taiwan, which is currently recognized by 14 UN member states, ratified the treaty before the United Nations General Assembly's vote to transfer China's seat to the People's Republic of China (PRC) in 1971
- It prohibits the placing of nuclear weapons in space
- It limits the use of the Moon and all other celestial bodies to peaceful purposes only and establishes that space shall be free for exploration and use by all nations, but that no nation may claim sovereignty of outer space or any celestial body.
- The Outer Space Treaty does not ban military activities within space, military space forces, or the weaponization of space, except for the placement of weapons of mass destruction in space.
- It is mostly a non-armament treaty and offers insufficient and ambiguous regulations to newer space activities such as lunar and asteroid mining.

MOON TREATY

The Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, better known as the Moon Treaty or Moon Agreement, is a multilateral treaty that turns the jurisdiction of all celestial bodies (including the orbits around such bodies) over to the participant countries. Thus, all activities would conform to international law, including the United Nations Charter.

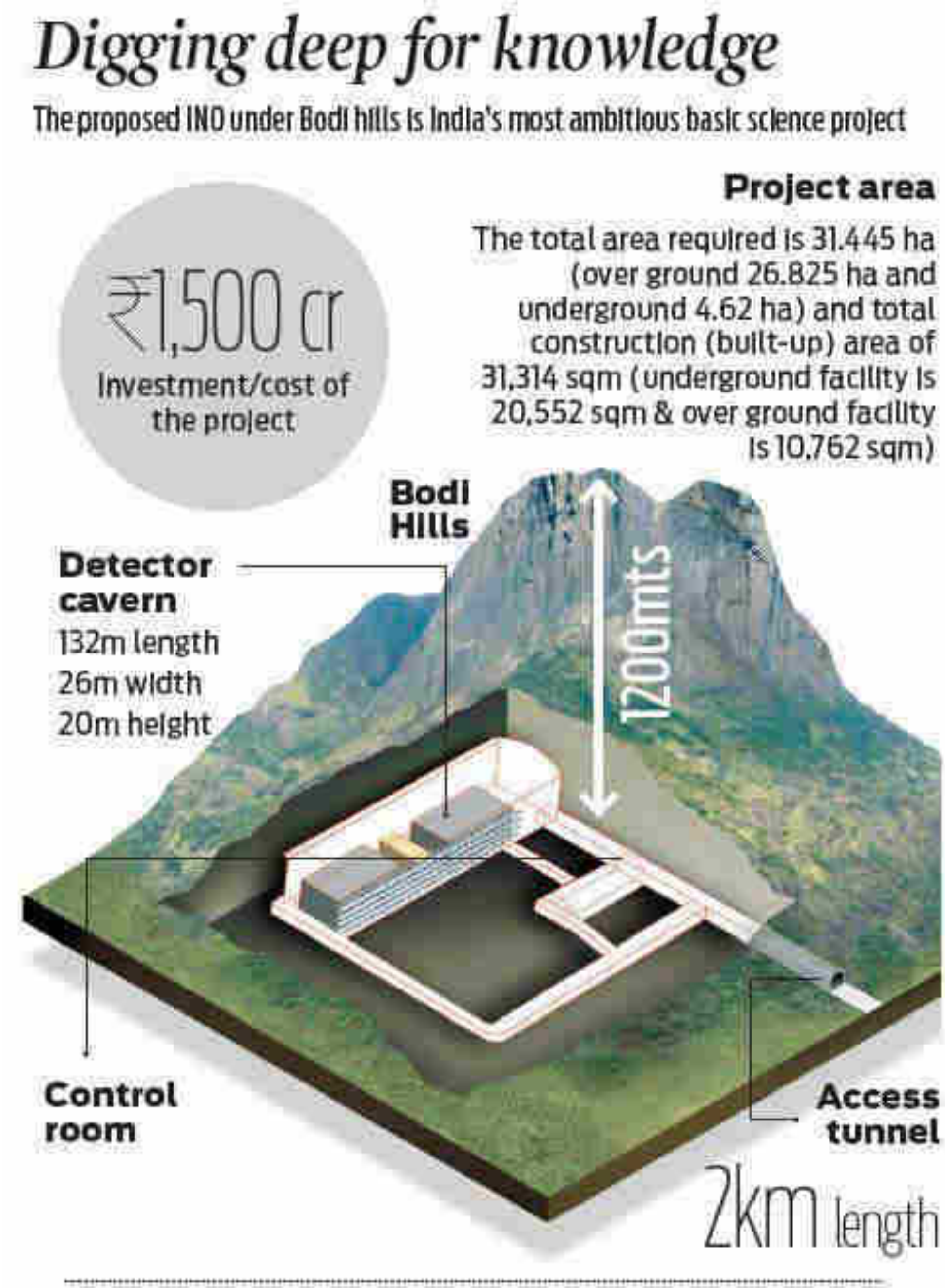
The countries or states who are intending to or have been engaging in self-launched human spaceflight, have not ratified the treaty (e.g. the United States, many members of the European Space Agency, Russia, China and Japan). Due to this, it has little to no relevance in international law. Till 2019, 18 states are parties to the treaty.

INDIA BASED NEUTRINO OBSERVATORY (INO) - PROJECT:

Approval has been granted by the Union cabinet for setting up of a Neutrino Observatory for studying fundamental particles called the neutrinos. The location of the Observatory would be in the Bodi West Hills region of the Theni district, about 110 kilometers west of Madurai in Tamil Nadu.

- INO involves the construction of an underground laboratory.

- The project location was initially decided to be located in the Nilgiris but later, on grounds that it was too close to tiger habitat, was moved to a cavern under a rocky mountain in the Bodi West Hills.
- It involves the Inter-Institutional Centre for High Energy Physics (IICHEP) and Iron Calorimeter Detector (ICAL).
- Approval has also been granted to construct a magnetized Iron Calorimeter to study the properties of the neutrino, specifically, the mass hierarchy in various types of neutrino.
- It will be the largest in the world weighing over 50,000 tonnes.
- The Department of Science and Technology and the Department of Atomic Energy jointly support the project.



INO PROJECT

(image source: INDIAN EXPRESS)

<u>What are Neutrinos?</u>

These are subatomic particles very similar to an electron, but they don't have any electrical charge and a very small mass, which might even be zero. Neutrinos are one of the most abundant particles in the universe, but they are very difficult to be detected because of their little interaction with matter.

Nuclear forces treat electrons and neutrinos identically; neither participate in the strong nuclear force, but both participate equally in the weak nuclear force. Particles with this property are termed leptons. In addition to the electron (and its antiparticle, the positron), the charged leptons include the muon (with a mass 200 times greater than that of the electron), the tau (with mass 3,500 times greater than that of the electron) and their anti-particles.

Similar to an electron, the muon and the tau, have accompanying neutrinos, which are called the muon-neutrino and tau-neutrino. The three neutrino types appear to be different.

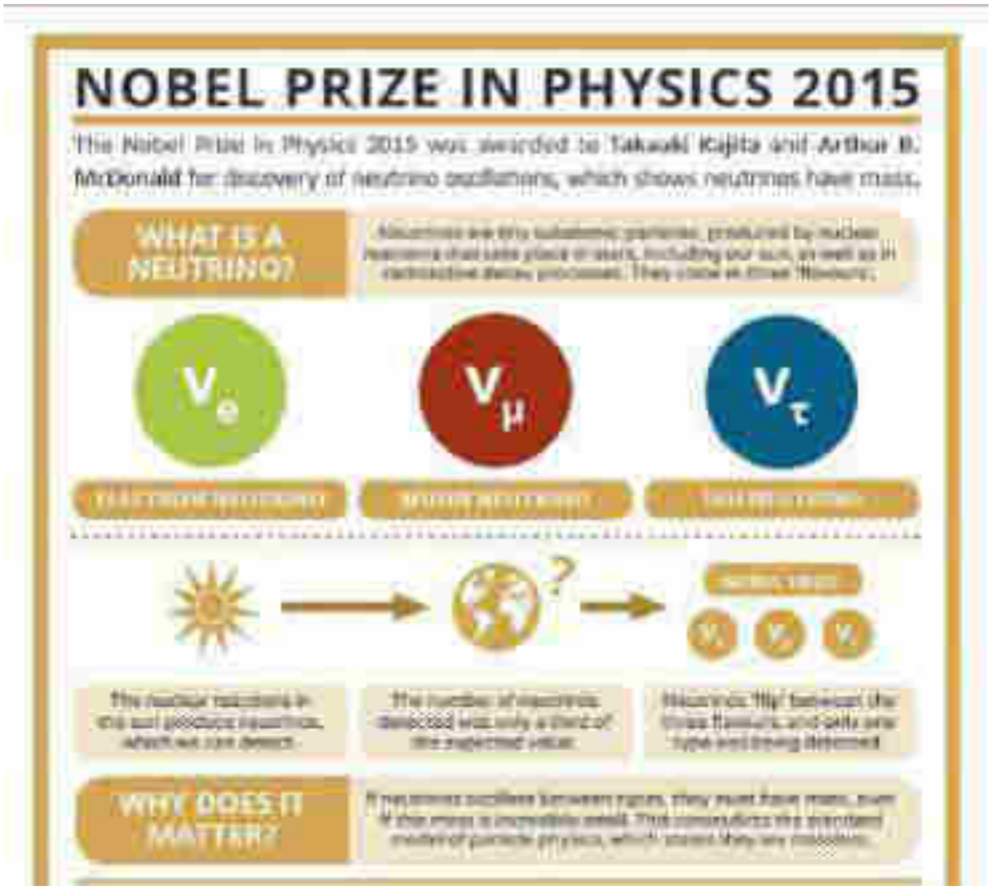
To detect neutrinos, very large and very sensitive detectors are required. Typically, a low-energy neutrino will travel through many light-years of normal matter before interacting with anything. Consequently, all terrestrial neutrino experiments rely on measuring the tiny fraction of neutrinos that interact in reasonably sized detectors. For example, in the Sudbury Neutrino Observatory, a 1000 ton heavy water solar-neutrino detector picks up about 10^{12} neutrinos each second. About 30 neutrinos per day are detected.

In 2015, the Nobel prize in physics was awarded to Takaaki Kajita and Arthur B. Mcdonald for discovering neutrino oscillations demonstrating that neutrinos have mass.Neutrinos are the least harmful of all elementary particles, as they almost never react with solid bodies.The mass of a neutron is 1.67×10-27 kg while the mass of a neutrino is of the order of 1×10-37kg. Hence, a neutrino is about 17 billion times lighter than a neutron. The two are incomparable.

Importance of INO:

- It will be the largest experimental facility to come up in the country. It will facilitate the development of cutting-edge technology and build sophisticated instruments.
- Neutrinos may have a role to play in nuclear non-proliferation through the remote monitoring of nuclear reactors.
- Understanding neutrinos could help in detection of oil and mineral deposits.

- They may open up a faster way to send data than the current ‘around the earth’ model, using towers, cables or satellites as they can pass through the Earth.
- Neutrinos will help in unraveling the deepest mystery of the universe, as they are believed to carry a lot of information.



<u>Neutrinos</u>

(Image source: chemeurope.com)

<u>Recent Development In Space Sector:</u>

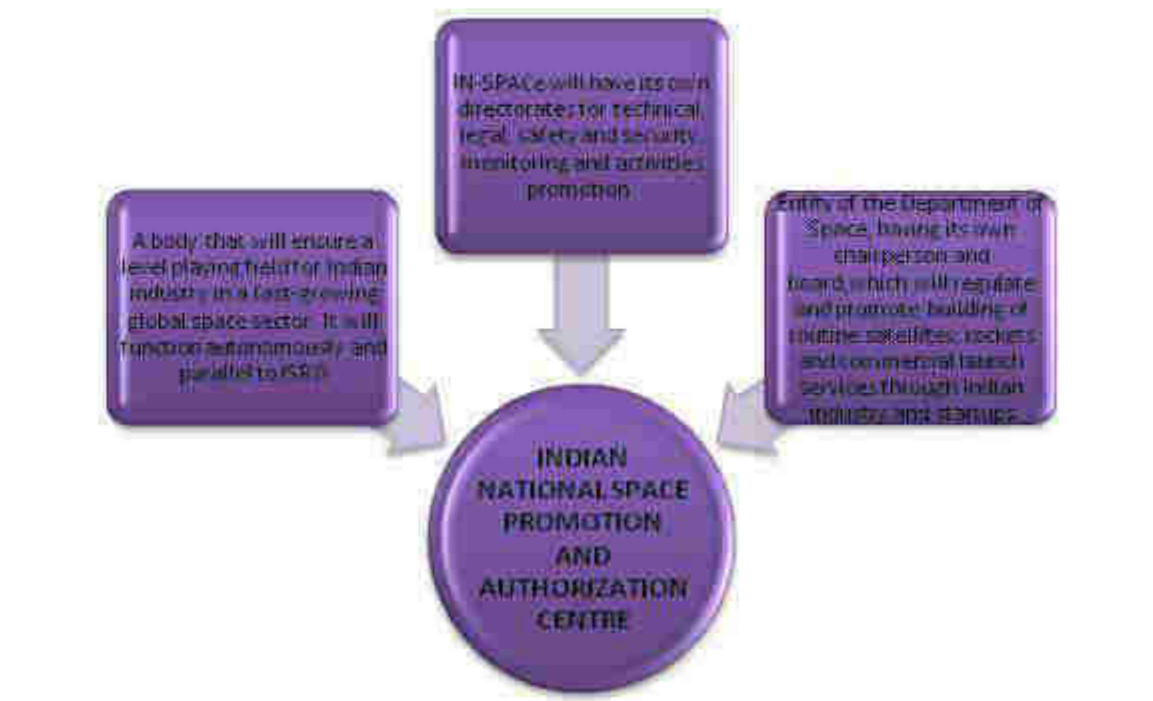
<u>BOOSTING PRIVATE PARTICIPATION IN SPACE ACTIVITIES-</u>

Under the **ATMANIRBHAR BHARAT ABHIYAAN** package and Reforms, it was announced that ;

- There shall be a level playing field provided to private companies in satellites, launches and space-based services.

- Predictable policy and regulatory environment to private players will be provided.
- Private sector will be allowed to use ISRO facilities and other relevant assets to improve their capacities.
- Future projects for planetary exploration, outer space travel etc shall also be open for the private sector.
- There will be liberal **Geo-spatial Data Policy** for providing remote-sensing data to tech-entrepreneurs.

IN-SPACE



CHAPTER 4: DEFENCE SECTOR TECHNOLOGY

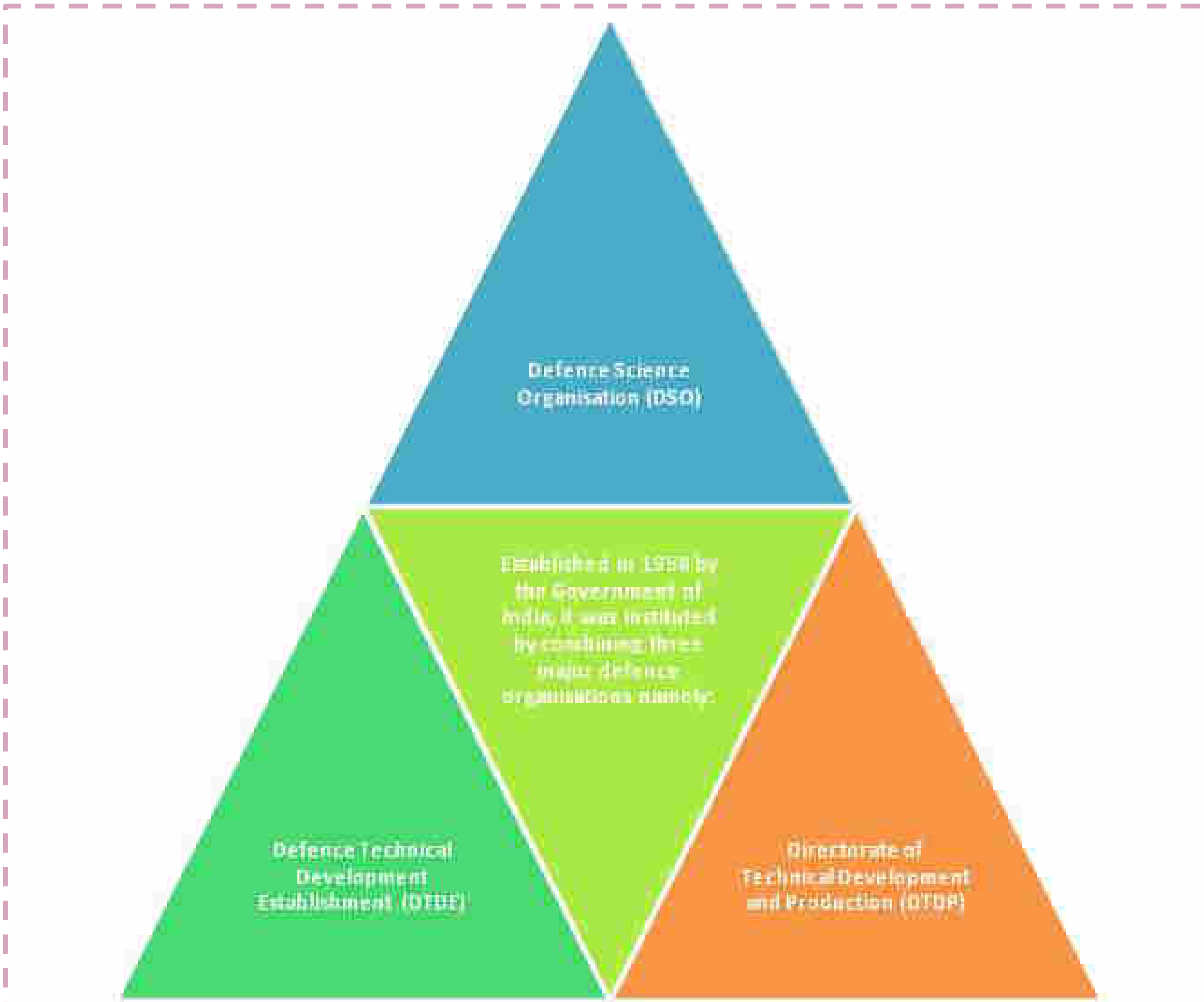
4.1 INTRODUCTION

In the last century, Science has transformed the world in almost all areas of society. The importance of technology in the field of defence is well realised. In the era of atomic bombs, ballistic missiles, and space warfare no country's defence forces can be deprived of the latest technology for defence purposes. Defence Research and Development organization (DRDO) has provided India with some of the promising missile technologies and state of art defence capacities which has improved the defence preparedness of India.

However, India has still not achieved the goal of becoming self reliant in Defence manufacturing and technology. It is still one of the largest importers of defence technology and is heavily dependent upon its strategic partners to fulfill its defence sector needs. This requires an urgent and sustained action and a long term blueprint for achieving self reliance and self capability in the defence sector.

DEFENCE RESEARCH AND DEVELOPMENT ORGANIZATION (DRDO)

It was established in 1958 by the Government of India, under the Ministry of Defence.



- With a project in 1960 on Surface to Air Missiles (SAM), the **Project Indigo** was the DRDO's first major defence project. This project was discontinued without any success.

Vision	Empowering the nation with state-of-the-art indigenous Defence technologies and systems.
Mission	Design, develop and lead to production state-of-the-art sensors, weapon systems, platforms and allied equipment for our Defence Services. Provide technological solutions to the Services to optimise combat effectiveness and to promote well-being of the troops. Develop infrastructure and committed quality manpower and build strong

	indigenous technology base.

DRDO is the Research and Development wing of the Ministry of Defence, Government of India. DRDO's pursuit of self-reliance and successful indigenous development and production of strategic systems and platforms such as Agni and Prithvi series of missiles; light combat aircraft, Tejas; multi-barrel rocket launcher, Pinaka; air defense system, Akash; a wide range of radars and electronic warfare systems; etc., have given quantum jump to India's military might, generating effective deterrence and providing crucial leverage.

Today, DRDO is a network of more than 50 laboratories which are deeply engaged in developing defense technologies covering various disciplines, like aeronautics, armaments, electronics, combat vehicles, engineering systems, instrumentation, missiles, advanced computing and simulation, special materials, naval systems, life sciences, training, information systems and agriculture.

To ensure private participation in defense technology development, DRDO engages with several private industrial units at regular intervals. Moreover, it takes up regular interactions with Confederation of Indian Industries (CII), FICCI, ASSOCHAM, etc.

4.2 MAJOR TECHNOLOGIES (DRDO)

Airborne Telemetry Receiving System:

Evaluation of medium and long-range missiles requires physical parameters of subsystems as well as navigational data acquired and recorded through telemetry. The instruments to be deployed for adequate coverage of the flight are ensured during launch, mid-course and terminal phases of the flight path. The tracking and telemetry systems deployed at the launch site ensure data reception requirements of launch and mid-course phases of the flight path. The maximum distance of signal reception is limited by the line-of-sight (LOS) conditions; the instruments located near the launch site will not be able to receive telemetry signals during the terminal phase of the flight path. To receive telemetry information in the final phase of trajectory, ship-borne measurement stations are deployed near the expected impact point.

However, the ship-borne instruments can receive telemetry data only up to a limited height above sea level because of the limitation of LOS. Also, for validation of anti-ship cruise missiles cruising at very low altitudes of approximately 5 to 10 m the conventional approach of ship-borne down range instrumentation will be less effective. To overcome the problems of reception of telemetry signals at low heights, DRDO has developed a comprehensive helicopter-borne measurement station to ensure the required range of straight visibility. Such systems available elsewhere are cost-prohibitive

All Electric Type Weapons Control System For-ICV:

An all-electric type weapon control system with independent stabilization has been developed indigenously by DRDO in association with private sector industry for the turret of **Infantry Combat Vehicle (ICV), Abhay**. The purpose of an all-electric drive (AED) is to position the 40 mm main gun of Abhay on to the target in azimuth and elevation and to provide twin-axis stabilization to the weapon platform against external disturbances.

It is an electromechanical system, which uses brush-less drives with specially designed backlash-free elevation and traverse gearboxes. It employs vector control technology. It uses state-of-the-art fiber optic gyros as feedback elements for stabilization and has real-time connectivity with Fire Control System and Battlefield Management System.

The system has been tested onboard vehicles on cross-country and has been successfully test-fired on static targets. Being an indigenous development, AED can be suitably configured to drive and stabilize similar weapons/allied platforms.

<u>Fig 4.1: ABHAY</u>

(Image source: DRDO)

Salient Features	Provides fire on move capability	Operates in various mode	Inbuilt provision for equipment testing	Interlocks for safe operation	Dual control through gunner and commander joysticks with override facility to commander

<u>Explosive Reactive Armours</u>

These armors disrupt and defeat the shaped charge jet of anti-tank missile warheads effectively and also provide protection to tanks against KE threats as well as heat. Have Provision for fitment of reactive elements in panels without removing the panels, thus fast up arming of the tank.

Explosive Reactive Armour (ERA) Mk-I

ERA Mk-I for Tank T-72 M1(CI Ajeya) has been developed by HEMRL for protecting modern anti-tank guided missiles like MILAN. This technology has been transferred to Ordnance Factories for production.

Salient Features

- Modular type of configuration on hull glacis
- Reduces the penetration of Shaped Charge warheads by ~ 70%
- No sympathetic detonation between adjacent panels and minimum collateral damage
- Easy fitment and replacement
- Least sensitivity and safe to handle
- Effective even after deep fording.

Explosive Reactive Armour (ERA) Mk-II

- Integral type configuration on hull glacis, in which the panels have been welded on the tank surface and a window for positioning of reactive elements.
- Adaptable to all the three tanks i.e. T-72, T-90 and Arjun Mk-II of Indian Army

- No sympathetic detonation between adjacent elements inside the panel and immune to detonation against small arms
- Additional weight on one tank: 1.5T
- Effective even after deep fording
- The product has been accepted by the Users and likely to be inducted for fitment on MBT Arjun Mk-I A and import substitute for T-90 Tanks.

Light Combat Aircraft:

The maiden flight of Light Combat Aircraft Technology Demonstrator 1 took place in 2001 which was a significant development that led to the entry of Light Combat Aircraft into the flight test program of DRDO.

It is a light multi-role jet military aircraft most coming from advanced trainers that have been modified or designed for engaging in light combat missions, either in a light strike or attack missions, surveillance or interdiction roles while some are keeping its trainer role. They are also slower than their bigger aircraft and most capable of running at subsonic speeds though some are capable of reaching Mach 1+. It is generally used for self-defense purposes or anti-hostile aircraft/helicopter missions not for air defense as lightweight fighters do. These aircraft are usually smaller and more lightly armed than the bigger multi-role or strike aircraft.

The light combat aircraft program was started in 1983, and the Project definition phase was started in 1989 while the full-scale engineering development phase started in 1993. The development of light combat aircraft is taken up by Aeronautical Development Agency (ADA) which is responsible for the design, project monitoring and promoting the development of advanced technology related to light combat aircraft. The Principal Partner of LCA is Hindustan Aeronautical Limited (HAL).

Light Combat Aircraft -Tejas:

The Light Combat Aircraft (LCA) program was started by the Government of India in 1984 when they established the Aeronautical Development Agency (ADA) to manage the LCA program.

- LCA Tejas was designed and developed by India's HAL (Hindustan Aeronautics Limited).
- It replaced the aging Mig 21 fighter planes.
- It was in 2003 that the Light Combat Aircraft program was named 'Tejas' (meaning radiance in Sanskrit) by the then PM Atal Bihari Vajpayee.
- It is the second supersonic fighter jet that was developed by HAL (the first one being HAL HF-24 Marut).
- LCA Tejas is a single-engine multi-role light combat aircraft.
- It is the lightest and smallest multi-role supersonic fighter aircraft in its class.
- It is designed to carry a range of air-to-air, air-to-surface, precision-guided and standoff weaponry.
- Tejas has a single-engine, compound Delta wing and has a tailless design.
- The idea behind the LCA program was to expand and develop India's indigenous aerospace capabilities.
- Since the 1970s, the MiG 21 planes have been the mainstay of the Indian Air Force. The primary goal of the LCA program was to replace the ageing MiGs.
- The secondary goal was the advancement of indigenous domestic aviation capabilities.
- HAL plans to deliver 123 Tejas aircraft to the Indian Air Force by 2024-25.

Specifications:

Tejas has a maximum payload capacity of 4000 kg. It is a single pilot single-engine aircraft that has a maximum take-off weight of 13,300 kg. It can attend the maximum speed of Mach 1.8. It has a general range of 850 km and a combat range of 500 km.

Tejas is a low-cost aircraft with a simple design. Hence, it is very attractive to cost-conscious nations in Asia.

Although currently, Tejas is not sold to other countries, Singapore, Egypt, Sri Lanka, the UAE, Turkmenistan and Malaysia have expressed interest in acquiring this aircraft.

Variants of Tejas:

- **Tejas Trainer:** 2-seater operational conversion trainer for training air force pilots.
- **LCA Navy**: Twin- and single-seat carrier-capable for the Indian Navy. However, the Navy has declared that the Tejas is too heavy for it to be operational from aircraft carriers (like INS Vikrant, INS Vikramaditya, etc.)

- **LCA Tejas AF MK2**: This is an improvement over the LCA Tejas Mk1 with a higher thrust engine.
- **LCA Tejas Navy MK2**: This is phase 2 of the LCA Navy variant.

Main Battle Tank-ARJUN:

Main Battle Tank (MBT) Arjun is a multi-laboratory program of DRDO with CVRDE as the lead Laboratory. It is a state-of-the-art tank with superior firepower, high mobility, and excellent protection. Twelve Mk 1 prototypes of MBT Arjun have been manufactured and their performance tests have provided satisfactory results. Some of the breakthroughs achieved by CVRDE during the development of MBT Arjun are in Engine, Transmission, Hydropneumatic Suspension, Hull and Turret, and Gun Control System.

Salient Features

The superior armor defeating capability of the indigenously developed Fin Stabilized Armour Piercing Discarding Sabot (FSAPDS) ammunition and 120 mm caliber rifled gun give MBT ARJUN an edge over contemporary world tanks. A computer-controlled integrated fire control system incorporating a day-cum-night stabilized sighting system guarantees a very high first-round hit probability and reduced reaction time to bring effective fire on targets.

The stabilization system for the main armament, slaved to the sighting equipment in elevation and azimuth, with a high and accurate laying speed, allows fire on the move.

The superior firepower of MBT is based on:

- The rifled 120 mm ARJUN gun together with the newly developed super velocity ammunition, can defeat any contemporary armor used in tanks. The electro-slag refined gun steel tube is autofrettaged to withstand higher gas pressures. A thermal jacket prevents irregular temperature distribution on to the tube due to the weather influences.
- A coaxial 7.62 mm machine gun for anti-personnel and a 12.7 mm machine gun for anti-aircraft and ground targets are provided as secondary weapons.

- Gunner's Main Sight consists of a day-sight, thermal sight, a laser range finder, and a stabilized head common to all the three channels. The common sighting head mirror is stabilized in elevation and azimuth. The day- sight provides dual magnification.
- The thermal imager provides night vision facility to the gunner and the commander to observe and engage targets in total darkness and the presence of smoke, dust, haze and light camouflage. Integral with the main sight is the laser range finder by which targets can be ranged accurately.
- Commander's panoramic sight enables the commander to effect all-round surveillance on the battlefield without removing his eyes from the sight and without being disturbed by the turret motion. The field of view is stabilized with the help of a two-axis rate gyro-mounted on the platform of the head mirror. The sight offers dual magnification.
- Two types of ammunition, viz, FSAPDS and HESH have been developed for this armament. The highly lethal FSAPDS ammunition which is the main battle ammunition of the tank has accounted itself admirably during the trials. Besides, the anti-helicopter round to combat the air threat to armour is also under development.
- Low ground pressure, high power-to-weight ratio and new design concepts in transmission suspension and running gear result in a highly mobile and agile weapon platform.

The remarkable mobility of MBT which also adds to its protection is the result of:

- Due to the high power-to-weight ratio and low specific ground pressure, MBT is fast, highly maneuverable and extremely mobile to cross the most difficult terrain with ease. High acceleration rapid braking capabilities with excellent steering characteristics make MBT agile on the battlefield. Adequate fuel storage capacity and relatively low fuel consumption allow for an optimal operational range.
- An important criterion for the mobility of any AFV is the effective performance of the driver. Excellent vision systems both for day and night provide the most effective means of observation in all battlefield conditions. The need to keep the crew's fatigue including that of the driver at the minimum level over long periods of continuous operation has been taken care of.

- All-round protection from anti-tank ammunition is achieved by t~e newly developed KANCHAN armor to a degree much higher than available in present generation tanks. A high degree of immunity is achieved.
- Fire Power:-Accurate and fast target acquisition capability during day and night and in all types of weather
- Shortest possible reaction time during combat engagements.
- Ability to accurately engage targets on move.
- Capability to destroy all possible enemy armor at maximum battle ranges
- Excellent first hit probability.

4.3 INTEGRATED GUIDED MISSILES DEVELOPMENT PROGRAMME (IGMDP)

It was an Indian Ministry of Defence programme for the research and development of the comprehensive range of missiles. The programme was managed by the Defence Research and Development Organisation (DRDO) and Ordnance Factories Board in partnership with other Indian government organizations. The IGMDP project started in the year 1982–83 under the leadership of Abdul Kalam and completed in 2008 under his able leadership after these strategic missiles were successfully developed.

During the phase of 1980s, the Defence Research and Development Laboratory (DRDL) had developed competence and expertise in the fields of propulsion, navigation and manufacture of aerospace materials based on the Soviet rocketry technologies. Thus, India's political leadership, which included Prime Minister Indira Gandhi, Defence Minister R. Venkataraman, V.S. Arunachalam (Political Advisor to the Defence Minister), decided that all these technologies should be consolidated which led to the initiation of the Integrated Guided Missile Development Programme with Dr. APJ Abdul Kalam, to conceive and lead it. While the scientists proposed the development of each missile consecutively, the Defence Minister R. Venkataraman asked them to reconsider and develop all the missiles simultaneously. Thus, four projects, to be pursued concurrently, were part of IGMDP.

- PRITHVI- Short range surface-to-surface missile
- TRISHUL-Short range low-level surface-to-air missile
- AKASH- Medium range surface-to-air missile

- NAG- Third-generation anti-tank missile
- Agni Series of missile
- AGNI V-Long range intercontinental ballistic missile

Brief description of the missiles under the Integrated Guided Missile Development Development Programme:

1.PRITHVI

- Prithvi is a tactical surface-to-surface short-range ballistic missile (SRBM) developed by DRDO of India under the Integrated Guided Missile Development Program (IGMDP).
- It is deployed by India's Strategic Forces Command.
- It is the first in the series of missiles to be developed under the programme.
- The missile is capable of running on solid or liquid or both the fuels and carries nuclear warheads.

The Prithvi project encompassed developing three variants for Army, air force and Indian Navy.

Dhanush

Dhanush is a variant of the surface-to-surface or ship-to-ship Prithvi III missile, which has been developed for the Indian Navy. It is capable of carrying both conventional as well as nuclear warheads with pay-load capacity of 500 kg-1000 kg and can strike targets in the range of 350 km

2. AKASH MISSILE:

Two rounds of medium range nuclear capable surface-to-air missile Akash was test fired successfully from a defence test facility off the Odisha coast against two unmanned aerial vehicles.

- The Akash missile is capable of engaging aerial threats upto a distance of approximately 25 kms.
- The Akash missile having a multi target, multi directional, all weather air-defence system consisting of surveillance and tracking radars, could take off at a speed of around 2.5 Mach and reach a high altitude of 18 kms and as low as 30 meters.
- The missiles were test fired against a Pilot less target aircraft (PTA) , Unmanned Aerial Vehicle (UAV) and Para-barrel, twice.
- More than 250 industries are involved in the production and supply of various subsystems/components with military/aerospace grade quality and ground systems developed by the DRDO for Akash missile.

Fig 4.2 Akash Missile

(image source :The Hindu)

3. NAG (ANTI TANK GUIDED MISSILE):

NAG is an anti-tank guided missile that can destroy enemy tanks miles away. It is the world's finest all-weather missile with day and night capabilities that comes in four variants that are capable of being launched from land and air.The fire-and-forget missile is developed by DRDO under the integrated guided missile development programme (IGMDP).

NAG has a minimum range of 500 metres and a maximum of 20 km, depending on the launch type. Its top speed is 230 meter/second

- it is a fire-and-forget, lock-on-before-launch missile.
- The missile locks the target before its release.
- NAG missiles can locate the enemy tanks with the help of thermal imaging and After identifying the target, a thermal reference image of the target is captured and locked into the Nag's seeker system.
- The missile is launched towards the locked target with this reference image.As the missile moves towards the target at a high speed, it keeps capturing target images and cross-check it simultaneously with the reference image.
- Any deviations from the set path is corrected through Nag's four control fins. It all happens at a very high speed of 230 meter/second and within a range of 4-20 km, depending on the launch type.

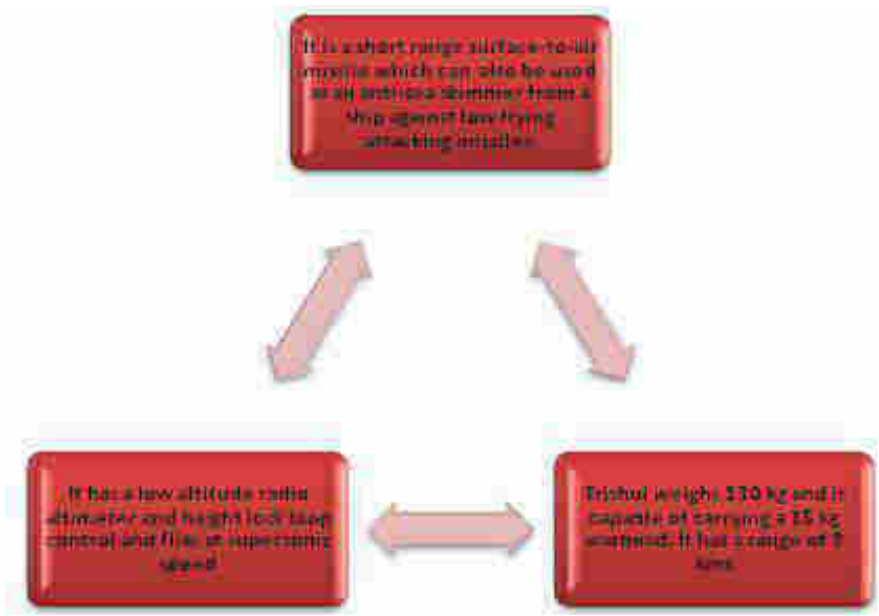
Fig 4.3: NAG anti-tank guided missile

(*Image source: DRDO)*

NAG VARIANTS:

Prospina	**HELINA**	**Man Portable Anti-tank Guided Missile (MPATGM)**
Prospina with range 500m-4km, is the land version meant for infantry, and can be launched from a tracking-cum-launch vehicle known as NAMICA (Nag Missile Carrier). The launch system is mounted on light infantry vehicle BMP-2 and can carry up to six missiles. Each launcher can fire four missiles in one minute..	It is a helicopter-launched version of NAG with an extended range of 7 to 10 km. The launch system is mounted on HAL "Rudra" helicopter using "Rudrastra" twin-launcher system and HAL Light Combat Helicopters. The launch system is used by both the Indian Army and Air Force. **Helina (SANT) (15-20 km):** This is an upgraded version of the third-generation Helina with an extended range. The higher range and a new nose-mounted radar seeker help the missile launch platform stay at a safe distance, to evade enemy fire	This version is lighter (14.5 kg) in comparison to other variants and can be launched from the shoulder. It has a strike range of 2.5 km.

4. TRISHUL:



5. AGNI :

The Agni missile series comprises medium and Intercontinental range ballistic missiles developed by the Defence Research and Development Organisation (DRDO), India. Agni missile systems are long-range ballistic missiles capable of carrying nuclear warheads.

The technology demonstrator version of Agni was the first missile of the series which was developed under the integrated guided missile development programme and was tested in 1989. The Agni series of missiles comprises 6 variants namely Agni-I, Agni-II, Agni-III, Agni-IV, Agni-V, and Agni-VI.

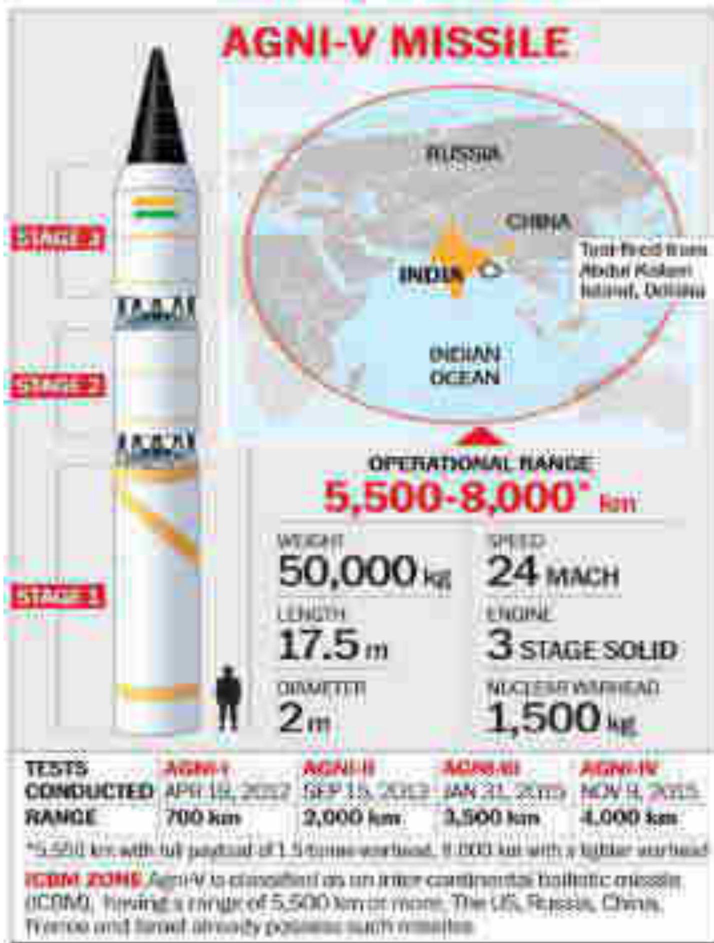


Fig 4.4 Agni V and other Agni Series

(*Image source*: tribuneIndia.com)

AGNI SERIES MISSILES:

Agni-I

Agni 1 was first launched as a technology demonstrator in 1989 and was a solid fuelled first stage missile Technology capable of carrying 1000 kg conventional payload or a nuclear warhead. This technology demonstrator later evolved into the Agni 1 missile.

However, AGNI 2 was first developed and tested in 1999 while later on Agni 1 with a range of 700 was test-fired in January 2002. Agni 1 is a one stage ballistic missile having a range of 700 to 900 km and is capable of carrying 1000 kg conventional warhead or a nuclear warhead at a speed of 2.5 km/s

It is a rail and road-mobile and is used by the Strategic Forces Command of the Indian Army. Agni 1 is less costly, simple, accurate and more mobile than Agni 2 missile.

Agni-II

It is a two-stage solid-fuel medium-range ballistic missile having a range of 2,000 to 2,500 km which can carry 1000 kg conventional payload or a nuclear warhead

It was successfully launched as a training exercise by the Strategic Forces Command in August 2012 and has been inducted into India's military arsenal, and Agni 2 missile is a part of India's "credible deterrence" against China and Pakistan. It can reach all of Pakistan and large parts of south and South-Eastern China.

Agni-III

This missile is the successor of Agni 2 and is a part of India's credible minimum deterrence and nuclear triad. It comprises a two-stage solid-fuelled system, having a range of 3500 to 5000 km which makes it possible to engage targets deep inside the neighbouring countries.

It is capable of carrying 1.5 tons of conventional or nuclear warhead. Agni 3 was inducted into the Indian armed forces in June 2011.

Agni-IV

It is the fourth missile of Agni series having a range of 2500 km to 3700 km. It is also known as Agni 2 prime or Agni-IIA as it is an advanced version of Agni 2 with sophisticated and lighter materials with a re-entry heat shield that provides it with better efficiency and higher range performance

It uses a two-stage solid propulsion system to carry conventional or nuclear warheads of 1000 kg.

Agni V

Agni-V is a solid-fueled intercontinental ballistic missile (ICBM) developed by Defence Research and Development Organisation (DRDO) of India. It will greatly expand India's reach to strike targets more than 5,500 km away.

Agni-V ICBM has been designed with the addition of a third composite stage to the two-stage Agni-III missile.

AGNI V is 17.5-metre-long and would be a canister launch missile system to ensure that it has the requisite operational flexibility and can be swiftly transported and fired from anywhere.

Agni-VI

It is an Intercontinental ballistic missile proposed to be developed by DRDO. It will be a three-stage ballistic missile with Multiple Independently Targetable Reentry Vehicle (MIRV) and Manoeuvrable Re-entry Vehicle (MaRV). It is proposed that Agni 6 will have a strike range of 8000 to 10000 km.

The missile will be capable of being launched from submarines as well as from land. It is expected that the missile will carry up to 10 MIRV warheads.

The missile will be capable of being launched from submarines as well as from land. It is expected that the missile will carry up to 10 MIRV warheads

Fig 4.5 Missiles of India

(image source:India.com)

4.4 OTHER MISSILES BY DRDO

NIRBHAY MISSILE

- Nirbhay is an all-weather low-cost, long-range subsonic cruise missile with stealth and high accuracy designed and developed in India by the DRDO.
- The missile has a range of more than 1000 km. It weighs about one tonne and has a length of 6 meters.
- Its relatively slow flight speed allows it to navigate its way precisely to the target.
- The Nirbhay cruise missile is an Indian version of the American Tomahawk.
- The missile is capable of being launched from multiple platforms on land, sea and air.
- 'Nirbhay' missile can travel with a turbofan or turbojet engine and is guided by a highly advanced inertial navigation system indigenously developed by the Research Centre Imarat (RCI),
- The cruise missile is expected to supplement the Indo-Russian joint venture supersonic cruise missile BrahMos, which can carry warheads up to 290 kilometers.
- In particular, Nirbhay is being adapted for the Indo/Russian Su-30MKI. The missile is capable of carrying nuclear warheads.
- With two side wings, the missile is capable of flying at different altitudes ranging from 500 m to 4 km above the ground and can also fly at low altitudes (like low tree level) to avoid detection by enemy radar.

K-MISSILE FAMILY

The K family of missiles named after Indian scientist and former president A. P. J. Abdul Kalam is a series of submarine-launched ballistic missiles (SLBM) developed by India to boost its second-strike capabilities and thus augment its nuclear deterrence. Information about this family of missiles has mostly been kept classified. The "K" missiles are believed to be faster, lighter and stealthier than their Agni missile family

The K missiles are being developed by DRDO in cooperation with Bharat Dynamics Limited, these missions are generally used by Indian Navy Services (INS).

K-15 /Sagarika	K-4	K-5	K-6
The Sagarika/K-15 missile is the SLBM version of the land-based Shaurya Missile. With a shorter range than K-4 missiles, it is to be integrated with Arihant class submarines concurrently developed for the use of Indian Navy. Sagarika/K-15 was developed at the DRDO's missile complex in Hyderabad. The complex consists of the Defence Research and Development Laboratory (DRDL), the Advanced Systems Laboratory (ASL) and the Research Centre, Imarat (RCI).	K-4 is an intermediate-range submarine-launched ballistic missile under development by DRDO. It is a 10 m long missile weighing 20 tonnes, capable of carrying a 2-tonne payload up to a range of 3,500 km. INS Arihant, first of the Arihant Class Submarines, will be able to carry 4 K-4 missiles. The K-4 missile was successfully tested on 24 March 2014 from an underwater pontoon submerged 30 m deep. India successfully test-fired the 3,500 km strike range nuclear-capable K-4 submarine-launched ballistic	K-5 missile is reportedly being developed by Defence Research and Development Organisation (DRDO) for the Indian strategic forces' underwater platforms. It will arm the future variants of Arihant class submarines of the Indian Navy. Reportedly, DRDO is in the process of developing a submarine-launched solid-fuel missile with a maximum range of 5,000 kilometres.	K-6 missile is SLBM which is reportedly under development by Defence Research and Development Organisation (DRDO)'s Advanced Naval Systems Laboratory in Hyderabad. It is a three-stage solid-fuel MIRV capable missile with a length of 12m, a width of 2m, a payload of 2-3 tonne warhead and a maximum range of 6,000 km. It will arm the S5 class of ballistic missile submarines of the Indian Navy.

DRDL designed and developed the missile, while the ASL provided the motors and propulsion systems. The RCI's contribution was in avionics, including control and guidance systems and inertial navigation systems. Medium range K-15 ballistic missile has a range between 700 km to 1,500 km with a varying payload. This will also get help from the Indian Regional Navigation Satellite System (IRNSS) to ensure guaranteed national access to precision navigation. These will enable high accuracy required for precision strike. The last developmental test of	missile off the coast of Andhra Pradesh on 19 January 2020		

the missile was conducted on 28 January 2013 from an underwater launch platform off the coast of Visakhapatnam.			

These 'K' missiles are important for India's nuclear deterrence arsenal because they provide India with a much needed ideal and invulnerable second-strike capability stated in India's Nuclear Doctrine and thus shift the balance of power in India's favour in Asian region.

SHAURYA MISSILE

The Shaurya is a hypersonic surface-to-surface ballistic missile, developed by Defence Research & Development Organization (DRDO) of India.	The Shaurya is a 6.2 ft canister launched missile, with a 10 m length, and 0.74 m diameter with a range of 700 to 1 900 km and a payload weight of 180 to 1 000 kg. It can carry conventional or nuclear warheads.	It is a land variant of Indian K-15 submarine-launched missile. A number of tests were conducted before the missile was officially inducted into service in 2013. It Fulfils the tactical need of the country in offensive/defensive scenarios. The canister launch capability improves the mobility of the system even in rough terrains and bad weather.
The Shaurya uses a two stage propulsion system solid propellants to attain a speed of Mach 7.5 and altitude of 40	The two stage propulsion starts with the first stage solid fuel booster pushing the missile to a 5 km low	The SHAURYA missile has a hypersonic speed which offers minimal chance of getting destroyed by any

km. It has been incorporated with an advanced ring laser gyroscope, resulting in a good accuracy of 20-30 m CEP Circular Error Probable (CEP).	atmospheric pressure altitude. At this point the second stage starts and an inter-stage coupling mechanism (softstage) separates the missile parts. The second stage payload rises to its flight altitude and conducts in-flight maneuvers to increase the accuracy before plummeting towards it during the atmospheric re-entry.	interceptor missile. Also , the missile is highly maneuverable like a cruise missile and has reduced signature, rendering it invisible to the satellites to a very high extent.Further improvements to the missile system include better operational range, accuracy and increased payload capability.

BRAHMOS MISSILE

BRAHMOS is a two-stage missile with a solid propellant booster engine. The second stage or the liquid ramjet then takes the missile closer to 3 Mach speed in cruise phase. BRAHMOS has Stealth technology and guidance system with advanced embedded software

It has a flight range of up to 290-km with supersonic speed all through the flight, leading to shorter flight time, consequently ensuring lower dispersion of targets, quicker engagement time and non-interception by any known weapon system in the world.

It operates on 'Fire and Forget Principle', adopting varieties of flights on its way to the target. Due to large kinetic energy on impact, Its destructive power is enhanced. Its cruising altitude could be up to 15 km, and terminal altitude is as low as 10 meters. It carries a conventional warhead weighing 200 to 300 kgs.

Fig 4.6 BrahMos Missile

(IMAGE SOURCE: THE HINDU)

Status:

BRAHMOS is the first supersonic cruise missile known to be in service. Induction of the first version of the BRAHMOS Weapon Complex in the Indian Navy commenced from 2005 with INS Rajput as the first ship. All future ships being built and ships coming for mid-life up-gradation will be fitted with the missile. The Indian Army has also inducted three regiments of BRAHMOS supersonic cruise missile.

In-Service:

Ship-based Weapon Complex (Inclined & Vertical Configuration)

Land-based Weapon Complex (Vertical Launch Configuration from Mobile Autonomous Launcher).

In Progress

Air launch version (successfully test-fired in 2017, creating history)

The canisterised missile is capable of being launched vertically from underwater and had been successfully flight tested from a submerged platform. Deployment depends on the requirement of the Indian Navy or navies of friendly countries.

The air-launched version has been developed and has lesser weight and additional rear fins for aerodynamic stability during separation from the aircraft during launch. The missile has gone through a complete cycle of ground trials. The required modifications in SU-30 MKI for interface with the missile launcher and integration with the weapon control of the aircraft are being carried out together with Indian Air Force and Sukhoi Design Bureau. The BRAHMOS missile created history on 22 November 2017 after it was successfully flight-tested for the first time from the Indian Air Force's (IAF) frontline fighter aircraft Sukhoi-30MKI against a sea-based target in the Bay of Bengal.

Difference Between Cruise And Ballistic Missile:

Cruise missiles are **unmanned self-propelled guided missiles** that can carry large payloads with high precision. The missile is guided entirely to the target under its power. These are known for their **low-level flight,** closer and horizontal to the surface which helps them to avoid detection from anti-missile systems. They can be launched from air, land, ship or submarine.

Based on the speed they can be categorized as Subsonic cruise missile(Speed around **0.8 Mach)**, Supersonic Cruise missile: Speed around **2-3 Mach**, Hypersonic Cruise Missile: Speed is more than **5 Mach.**

On the other hand, a ballistic missile follows **a ballistic trajectory (projectile trajectory)** over most of its flight path. Unlike cruise missiles that remain in the same atmosphere, a ballistic missile changes their atmosphere. It can **travel well outside the atmosphere** and then warhead detaches and falls back to the earth.

It depends upon gravity to reach its target.

With a high terminal speed of around **5000m/sec**, ballistic missiles have shorter time available making them **harder to intercept than cruise missiles. Ballistic** missiles flying over the atmosphere have **a much longer range than possible for cruise missiles of the same size.**

BRAHMOS II MISSILE

- BrahMos-II or BrahMos-2 or BrahMos Mark II is a hypersonic cruise missile currently under joint development by Russia's NPO Mashinostroyenia and India's Defence Research and Development Organisation, which have together formed BrahMos Aerospace Private Limited.
- It is the second of the BrahMos series of cruise missiles.
- The BrahMos-II is expected to have a range of 450 km and a speed of Mach 7.
- The missile will be propelled by a scramjet airbreathing jet engine During the cruise stage of flight the
- It is expected to be ready for testing by 2020.

ASTRA MISSILE

- Astra is the Beyond Visual Range Air to Air Missile (BVRAAM) developed by DRDO (Defence Research and Development Organisation).
- It can engage aerial targets at a range of 80 km – 110 km. It has been integrated with Sukhoi 30 Mki, Mirage 2000, LCA, MiG-29 fighter aircraft.
- Astra is equipped with electronic counter-countermeasures to allow operation even during enemy attempts to jam the seeker using electronic countermeasures.
- It carries a 15 kg high explosive warhead activated by a proximity fuse.
- The maximum range of Astra is 160 km under the head-on chase mode and 40 km in tail chase mode.
- The maximum range is achieved when the missile launches from an altitude of 3 km . while from an altitude of 2 km, the range drops to 144 km and when it is launched from sea level, the range drops further to 121 km.

SOLID FUELLED DUCTED RAMJET (SFDR):

Defense Research and Development Organisation (DRDO) successfully flight tested the second indigenously developed ‘Solid Fuel Ducted Ramjet (SFDR)’ propulsion based missile system on 8th February 2019 from ITR, Chandipur, Odisha.

Details :

- It will facilitate the development of long-range air-to-air missiles in the country.

- The ramjet propulsion system used in it acts as an oxidizer, and the solid propellant reacts with the air flowing through a solid propellant duct.
- Ramjet uses the air as an oxidizer just like a jet engine, unlike conventional rockets that carry propellant and oxidizer. Therefore the weight of the fuel required is eliminated.
- The SFDR propulsion is designed in such a way that it allows for an up and down throttling.
- This further lets the missile to amplify its speed until it reaches the terminal phase of the flight.
- The speed increases until the point when sharp turns are required to search for highly maneuvering targets.

Background

- The first flight of SFDR, developed under a joint Indo-Russian R&D project, was tested in 2018. It had achieved the speed of Mach 3.
- The Indian SFDR will be used as variants of missiles such as the advanced version of ASTRA.

PRALAY MISSILE:

- It is a surface to surface solid fuelled guided short-range ballistic missile.
- The missile is based on the Prithvi Defence Vehicle, which is a part of the Indian Ballistic Missile Defence Programme.
- It carries a payload of 1 tonne and can strike targets ranging up to 350 km away.
- It can travel up to 500 km if the payload is halved.
- It can evade ballistic missile defense systems and can fly faster than the conventional missiles in its class.
- It can be launched from its own canister-based transport erector launcher.

ASHWIN/ADVANCED AIR DEFENCE (AAD):

- It is a single-stage solid rocket propelled guided missile consisting of Akash missiles.
- It is capable of endo-atmospheric interception that is; to intercept incoming ballistic missiles at altitudes of up to 30km ().

- The AAD is equipped with an inertial navigation system, advanced computer and an electromechanical activator.

PRITHVI AIR DEFENCE (PAD) SYSTEM:

- The PRITHVI AIR DEFENCE will be able to tackle incoming missiles at ranges of 80-120 km (exo-atmospheric interception).
- It is also known as Pradyumna and comprises a two-stage missile based on the Prithvi missile.
- The first stage is liquid-fuelled, and the second stage is solid-fuelled.
- The missile is equipped with maneuver thrusters for lateral acceleration.
- It can engage the targets of the ballistic missiles up to a range of 300km-2,000km at a speed of Mach 5.
- It has a long-range tracking radar for target acquisition and fire control.

Note:- Both Advanced Air Defence and Prithvi Air Defence systems form part of India's Ballistic Missile Defence Programme.

4.5 MISSION SHAKTI:

An Anti-Satellite (A-SAT) missile test named 'Mission Shakti' from Dr APJ Abdul Kalam Island in Odisha was conducted by Defence Research and Development Organisation (DRDO). DRDO-developed Ballistic Missile Defence (BMD) Interceptor Missile successfully engaged an Indian orbiting target satellite in Low Earth Orbit (LEO) in a 'Hit to Kill' mode. The interceptor missile was a three-stage missile with two solid rocket boosters.

It is a vindication of the strength and robust nature of DRDO's programs and has also demonstrated the nation's capability to defend its assets in outer space.

India joins a select group of nations, which have such capability, with the launch of ANTI SATELLITE MISSILE. The test has once again proven the capability of indigenous weapon systems.

Anti-satellite (ASAT) System

- It is a missile-based system to attack moving satellites.
- It is of 2 kinds— based on launching from the ground or planes.
- Defense Research and Development Organisation (DRDO) has -developed an Anti-satellite (ASAT)completely indigenously.

Anti-satellite (ASAT) attacks can take a variety of forms and serve a range of goals. For example, they may cause temporary, reversible interference, or they may be intended to cause permanent damage. They may target the satellite, the ground station, or the links between them. They may be overt, or they may be intended to be covert and thus not attributable to the attacker. The ASAT system may be based on the ground or in space. It may be relatively simple or require sophisticated technology appropriate to a space-faring nation. It may be able to interfere only with satellites in low earth orbit, or it may reach all the way to geostationary altitude.

Details:

They are generally of two types: kinetic and non-kinetic.

Kinetic:- The kinetic ASAT systems must physically strike an object to destroy it. Examples of kinetic ASATs include ballistic missiles, drones that drag an object out of orbit or detonate explosives in proximity to the object, or any item launched to coincide with the passage of a target satellite.

This means any space asset, even a communications satellite, could become an ASAT if it is used to physically destroy another space object.

Non - Kinetic ASAT systems: A variety of nonphysical means can be used to disable or destroy a space object.

These include frequency jamming, blinding lasers or cyberattacks. These methods can also render an object useless without causing the target to break up and fragment absent additional forces intervening.

ASATs can be used to intercept and jam communication or military satellites of enemy countries in the time of war and stop them from communicating with their soldiers. It can also be used to access critical information about troop movements or incoming missiles.

The anti-satellite weapons can even undertake pellet cloud attacks on the enemy's low orbit satellites. Other ASAT capabilities include cyber-attacks on space systems, Electro-Magnetic Pulse (EMP) explosion devices, directed energy (laser-based) weapons and targeted missiles for the destruction of satellites to sabotage the enemy's military operations. Although no ASAT system has yet been put to use in the actual war, several nations have shot down their own (defunct) satellites to exhibit their ASAT prowess in a show of power.

The range of an ASAT is limited and depends on where it is launched from. Satellites above the range of 20,000 kilometers are out of range. The US and Russia have the capabilities of launching an ASAT from the ship, land and space, while India, presently, has used a land installation.

AIRBORNE EARLY WARNING AND CONTROL SYSTEM (AEWC):

The Airborne Early Warning and Control System (AEW&C) in IOC configuration was developed by DRDO and handed over to the Indian Air Force (IAF), on 14 February during Aero India 2017 at Yelahanka Airbase in Bengaluru, and it was named **NETRA.**

Significance of the system

- The Airborne Surveillance System will transform the trajectory of air warfare.
- The AEW&C system has a state-of-the-art Active Electronically Scanned Radar, Secondary Surveillance Radar, Electronic and Communication Countermeasures, LOS (Line of Sight) data link, voice communication system and self-protection suite.
- A Complex tactical software has been developed for the fusion of information from the sensors, to provide the air situation picture along with intelligence to handle identification/classification threat assessment.
- Battle management functions are built in house to work as a network-centric system of Integrated Air Command & Control System (IACCS) node.
- This system has been developed and evaluated through collaborative efforts between DRDO and the IAF, with coordination for certification clearance and quality assurance by CEMILAC and DGAQA.
- The AEW&C system has undergone all weather and environmental trials and has been accepted by the IAF for induction.

ADVANCED LIGHT HELICOPTERS (ALH)

This program is an indigenously designed and developed 5.5-ton class multirole helicopter by RWRDC, HAL, Bengaluru. The Initial Operational Clearance (IOC) for helicopters was issued in 2001. The variants of the helicopter-like ALH Mk-I, ALH Mk-II, ALH Mk-III and ALH Mk-IV Rudra have been certified and cleared for operational use in various configurations like wheeled and skid versions.

The indigenously designed and developed Advanced Light Helicopter (ALH-DHRUV) is a twin-engine, multi-role(an aircraft that can perform multiple roles; such as -air to air combat, reconnaissance, electronic warfare etc) and multi-mission new generation helicopter in the 5.5-ton weight class.

The basic Helicopter is produced in a skid version and wheeled version. Dhruv is "type – Certified" for Military operations by the Centre for Military Airworthiness Certification (CEMILAC) and civil operations by the Directorate General of Civil Aviation (DGCA).

Certification of the utility military variant was completed in 2002 and that of the civil variant was completed in 2004. The deliveries of production series helicopters commenced from 2001-02 onwards. A total of 228 Helicopters have been produced by March 2017 including 216 for the Indian Armed Forces.

The major variants of Dhruv are classified as Dhruv Mk-I, Mk-II, Mk-III & Mk-IV.

4.6 SUBMARINES IN INDIA

A submarine is a watercraft that can travel and operate underwater. These are fully autonomous craft, capable of renewing its power and breathing air. Submarines are usually large crew vessels that can remain submerged for several weeks and even months.

Program for indigenous development of submarines was envisaged in India right in the 1990s which ultimately led to the culmination of several projects and acquisition of submarines from strategic partners. Indian Navy currently has 15 submarines in total and 2 more to join in this year. Indian Navy has 2 nuclear submarines- **INS Chakra** and **INS Arihant**

NUCLEAR POWERED SUBMARINES:

AKULA CLASS:

The construction of Akula II began in 1991, but it was suspended for ten years due to a lack of funds. A new Akula II submarine, the SSN Nerpa, for ten years was leased by the Indian Navy after signing an agreement with Russia. The vessel was commissioned to the Russian Navy in

December 2009. The submarine, renamed INS Chakra, was recommissioned by the Indian Navy in April 2012.

The submarine has a double-hulled configuration. The very low acoustic signature has been achieved by incremental design improvements to minimize noise generation and transmission – for example, the installation of active noise cancellation techniques.

The Akula Class carries up to 12 Granit submarine-launched cruise missiles. The missiles are fired from the 533mm torpedo launch tubes. Granit (Nato designation: SS-N-21 Sampson) has a range of about 3,000km and delivers a 200kt warhead. The land-attack Granit missile uses inertial and terrain-following guidance.

The submarine’s anti-ship missiles are the Novator SS-N-15 Starfish and the Novator SS-N-16 Stallion. The Starfish, fired from the 533mm tubes, has a target range of 45km. The Stallion, fired from the 650mm tubes, has a longer range of up to 100km. The submarine has eight torpedo launch tubes, four 650mm and four 533mm tubes.

The Akula can launch a range of anti-submarine and anti-surface vessel torpedoes. The Akula’s surface search radar is the Snoop Pair or the Snoop Half.

The submarine is fitted with the MGK 540 sonar system which provides automatic target detection in broad and narrow-band modes by active sonar. It gives the range, relative bearing and range rate. The sonar system can also be used in a passive, listening mode for the detection of hostile sonars. The sonar signal processor can detect and automatically classify targets as well as reject spurious acoustic noise sources and compensate for variable acoustic conditions.

ARIHANT CLASS:

INS Arihant class is the lead ship of India's Arihant class of nuclear-powered ballistic missile submarines.The 6,000-tonne vessel was built under the Advanced Technology Vessel (ATV) project at the Ship Building Centre in the port city of Visakhapatnam. It has the code name S2. The vessel is classified as a Strategic Strike Nuclear Submarine by India.

(Image source:defense 24.pi)

ARIGHAT:

INS Arighat which was previously called Aridhmaan is the second Arihant-class submarine. It is the second nuclear-powered ballistic missile submarine being built by India. It is being built under the Advanced Technology Vessel project to build nuclear submarines at the Ship Building Centre in Visakhapatnam.

CONVENTIONALLY POWERED SUBMARINES

This class of submarines run on diesel and electricity. They have a huge network of batteries which depend on the diesel generator for charging. These subs have to surface to charge their batteries. They can also **snorkel**, which means to travel just below the surface of the water with the periscope and the exhaust pipe above the water surface. Since they become vulnerable when they surface, these subs usually snorkel while charging their batteries. Once they charge the batteries, they dive into the ocean and run silently on battery power with the diesel generators shut down.

INS SHALKI:

- It is a shishumar class diesel electric submarine of Indian Navy
- It was the first ever submarine built in India and was launched in the year 1987.

SHISHUMAR CLASS:

In December 1981 the Indian government reached an agreement with Howaldtswerke-Deutsche Werft, a German organization based in Kiel, for a four-section contract covering four conventional submarines of the Type 1500 variant of the very successful boats of the U-206 class.

The four Shishumar boats are the Shishumar, Shankush, Shalki and Shankul. Built in Germany the first two boats were laid down in May and September 1982 for launching in December and May 1984 and completion in September and November 1986, while the last two boats, built in India, were laid down in June 1984 and September 1989 for launching in September 1989 and March 1992 and completion in February 1992 and May 1994.
The submarines are basically conventional with a single central bulkhead, their most notable operational features being the provision of an IKL-designed escape system.

The eight torpedo tubes are all grouped in the bows, and provision is made for the embarkation of six reload torpedoes. The Shishumar started a mid-life refit in 1999, with the other boats following in order of completion, and improvements that may be retrofitted are French Eledone sonar and an Indian action data system.

SINDHUGHOSH CLASS SUBMARINE:

- These are the kilo class diesel-electric submarines in active service with the Indian Navy
- These were designed as part of Project 877, and built under a contract between the Rosvooruzhenie and the MINISTRY OF DEFENCE, INDIA .

- SINDHUGHOSH submarines have a displacement of 3,000 tonnes,top speed of 18 Knots, a maximum diving depth of 300 meters, and are able to operate solo for 45 days with a crew of 53. The final unit was the first to be equipped with the 3M-54 anti-ship cruise missiles with a range of 220 km.

DELHI CLASS DESTROYER

The Delhi class are the third largest Naval warships built by the Mazagon Dock Limited, Mumbai. These destroyers have the facilities which can help them to act as a command unit and the Delhi class are equipped with facilities to operate in a nuclear, biological and chemical Warfare environment. Rafael Barak 1 air defence missile system will be deployed on these destroyers.

TIMELINE OF INDUCTION INTO SERVICE:

RAJPUT CLASS DESTROYERS:

Rajput class guided missile A frigate is a type of warship, having various sizes and roles over time destroyers are the modified versions of Soviet Kashin class destroyers built for the Indian Navy. The Other destroyers of 10 class include INS Rana, INS Ranjit, INS Ranvijay, and INS Ranvir.

Rajput class destroyers have anti-aircraft and anti-submarine warfare abilities for aircraft carrier task force for defending against submarines, cruise missiles, and low flying aircrafts.Rajput class destroyers were the first Naval warships to deploy Brahmos Supersonic Cruise missiles.

FRIGATES OF NAVY

SHIVALIK CLASS FRIGATES:

The Shivalik class or Project 17class FRIGATES largest currently in service with the Indian Navy. INS Shivalik is the first ship of this class and it is also the first naval warship built with stealth features in India. It was commissioned in the Indian Navy in April 2010

The three ships of this class are ;

- INS Satpura,
- INS Sahyadri and
- INS shivalik

built by Mazagon Dock Limited in Mumbai.

The armaments and defence systems of this class of frigate include surface to air missiles, medium range missiles, Brahmos anti-ship cruise missiles, torpedo launchers etc The successor of this class of frigates known as the project 17A has been started with the construction of its first ship in 2017.

TALWAR CLASS FRIGATES

Talwar class are guided missile frigates ,that are designed and built by Russia for the Navy and consist of a number of systems of Indian design in manufacture such as communication equipment, anti-submarine sensors etc.Talwar class has a displacement of 4000 tons with a speed of 30 knots. The talwar class frigates can be used for a variety of missions. INS Talwar, INS Trishul, INS Tarkash, INS Trikand, and INS Tabar are frigates of this class.

GODAVARI CLASS FRIGATES

Godavari class are guided missile frigate that are built under project 16 for the Indian Navy
The only ship of this class currently in service are- INS Ganga and Gomati

BRAHMAPUTRA CLASS FRIGATES

These are the guided missile frigates built and designed in India for the Navy. This class of frigates have been equipped with arms that include anti-submarine torpedoes, Barak surface to air missiles etc.

Brahmaputra class frigates have been named after Indian rivers viz. INS Brahmaputra, INS Betwa, and INS Beas.

CORVETTE

- It is the smallest class of vessels which is considered as a proper naval warship.
- A Corvette vessel is larger than a Coastal Patrol vessel and smaller than a traditional Frigate combat vessel.
- Five different classes of Corvette vessels are operated by INDIAN NAVY viz. Kamorta class, Kora class, Khurki class, Abhay class, and Veer class.

PATROL VESSELS

- It is a relatively small naval vessel designed for coastal defense duties.
- Patrol vessels consist of many designs
- They are generally used by the nation's navy, coast guard, police force, or customs and may be intended for marine or estuarine or river environments.
- They are commonly found engaged in various border protection roles, including anti-smuggling, anti-piracy, fisheries patrols, and immigration law enforcement.
- Patrol vessels often participate in rescue operations.

AIRCRAFT CARRIER

An aircraft carrier is a naval warship from which the fighter jets and airplanes may take off and land on them. It serves as a seagoing airbase and allows the naval force to project air power worldwide without the requirement for local bases for aircraft operations.

INS VIKRANT

- INS Vikrant was the first aircraft carrier to ever grace the arsenal of the Indian Navy.
- Initially starting life as the HMS Hercules of the British Royal Navy, the ship was re-christened as ‘Vikrant’ after purchase by the Indian Navy.
- The construction aircraft carrier began when World War II was in full swing, but would not be completed even after the end of the conflict.
- The incomplete ship was sold to the Indian Navy in 1957, who would finish its construction by the year 1961.
- INS Vikrant measured a length of 700ft, with a beam of 128 ft wide, considerably shorter than her sister ship, the INS Viraat, at 748 ft in length and 160 ft in width. The INS Vikrant was a bridge between full-sized fleet carriers and smaller, more economical escort carriers. In other words, INS Vikrant can be categorized as a “light fleet carrier”. Formally, INS Vikrant falls under the Majestic-class of aircraft carriers.
- The indicated horsepower of the ship totaled up to 40,000 (30,000 kW). It gave a speed of 25 knots which is about 46 km/hr. INS Vikrant could house about 1100 officers, men and aircrew.

INS VIKRAMADITYA

- INS Vikramaditya is the Indian Navy’s largest short take-off, but assisted recovery (STOBAR) aircraft carrier and warship converted from the Russian Navy’s decommissioned Admiral Gorshkov vertical take-off and landing (VTOL) missile cruiser carrier. INS Vikramaditya was commissioned into service in November 2013.
- The warship has been extensively refurbished with new propulsion systems, hull sections, sensors and flight deck. It was operationally deployed with a full complement of MiG-29 aircraft in May 2014.
- The vessel can carry more than 30 long-range multi-role fighters with anti-ship missiles, air-to-air missiles, guided bombs and rockets. The aircraft aboard the carrier include MiG 29K / Sea Harrier combat aircraft, Kamov 31 radar picket Airborne Early Warning (AEW) helicopter, Kamov 28 naval helicopter, Sea King helicopter, ALH-Dhruv, and Chetak helicopter.

4.7 UNMANNED AERIAL VEHICLE OF INDIA

The unmanned aerial vehicle (UAV) also known as a drone is an aircraft that works without a human pilot on board. The Unmanned Aerial Vehicles are a component of an unmanned aircraft system and generally comprise UAV, a ground-based controller, and a system of communications between the two. The flight of UAVs may operate with various degrees of autonomous modes: either under remote control by a human operator or autonomously by onboard computers.

The Unmanned Aerial Vehicle generally fall in one of the six functional categories:

- Target and decoys
- Reconnaissance
- Combat
- Logistics
- Research and Development
- Civil and commercial services

NISHANT:

- Nishant is a multi-mission Unmanned Aerial Vehicle launched using a Mobile Hydro pneumatic Launcher with Day/Night capability used for battlefield surveillance and reconnaissance, target tracking & localization, and artillery fire correction.
- A sophisticated image processing system is used for analyzing the images transmitted from the UAV.
- The air vehicle has autonomous flight capabilities and is controlled from a user-friendly Ground Control Station.
- Nishant is a highly mobile, compact and easily deployable system.
- It is recovered with the Aero Conical Parachute and impacts the attenuation system.
- Onboard flight control and navigation system enable the aircraft to fly in autonomous WayPoint Navigation mode.
- Nishant has been inducted in the Indian Army.

RUSTOM-1 and 2

- RUSTOM-1 is an all-composite, 800 kg class Short Range Remotely Piloted Aircraft System (SR-RPAS) having capabilities of Intelligence, Surveillance, Reconnaissance, Target Acquisition/ Tracking and Image Exploitation.
- Rustom-1 is the first Indian RPAS to have conventional take-off and landing capability.
- It has autonomous flight mode and Get-To-Home features.
- Rustom-1 RPAS has completed 65 flights and demonstrated flight endurance of 10 hrs, a range of 200 km and an altitude of 20,000 ft.
- Up-gradation of SR-RPAS with Automatic Take-off & Landing (ATOL), Synthetic Aperture Radar (SAR) and Store carrying capability is achievable.
- **Rustom 2** is being developed on the lines of predator drones of the US to carry out Intelligent, surveillance and reconnaissance (ISR) roles for the armed forces with an endurance of 24 hours.
- **Rustom 2** is capable of carrying different combinations of payloads like synthetic aperture radar, electronic intelligence systems, and situational awareness payloads.

PANCHI

- Panchi is a variant of Nishant (launcher based tactical UAV) with the capability of conventional take-off and landing.
- Panchi is integrated with all composite landing gear and has improved flight envelope and endurance.
- Panchi carries a stabilized payload platform.
- It carries payloads like daylight camera, infrared camera and laser designator.
- It is powered with an indigenously developed rotary Wankel engine.
- It has state of art systems, capable of surveillance, reconnaissance, target location detection and artillery fire correction.
- Five flights of Panchi have been completed proving the concept of conventional takeoff and landing.
- Data for aerodynamic, structure integrity and Flight control studies have been generated and analyzed.

AURA

- It is an autonomous unmanned combat air vehicle, being developed by the DRDO for the Indian Air Force.

- The design work on the UCAV is to be carried out by the Aeronautical Development Agency (ADA).
- The details of this project are not open to the public.
- AURA is a self-defending high-speed reconnaissance UAV with weapon firing capability.

HERON

- The Heron (Machatz-1) is a medium-altitude long-endurance unmanned aerial vehicle (UAV) developed by Israel Aerospace Industries.
- India has imported Heron from Israel and it has been inducted in all the three services.

4.8 RECENT DEVELOPMENTS IN THE DEFENCE SECTOR

PRAHAAR MISSILE

- It is a surface-to-surface short-range tactical ballistic missile which was test-fired by DRDO from Chandipur, Odisha.
- It was reported that the missile traveled a range of 200 km before hitting its simulated target, thereby successfully achieving all mission objectives.
- It was developed by the Defence Research and Development Organisation (DRDO) the prahaar weapon system is capable of carrying several different warheads like nuclear, high-explosives (HE) and submunitions among others.
- Also, the Indian Army weapon is capable of engaging and successfully neutralising a wide range of targets in different directions.
- The Prahaar weapon system is 7. Kms long and has a body diameter of 0.42m, with a launch weight of 1,280kg

PRANASH MISSILE

India is working on a new tactical ballistic missile capable of striking targets at a range of 200km. The surface-to-surface missile, being developed by the Defence Research and Development Organisation (DRDO), has been named Pranash.

The new weapon traces its origin to the Prahaar missile developed by the DRDO. The Prahaar has a range of 150km but the army wanted a weapon with a better range, which is why Pranash is being developed.

P-8I MARITIME SURVEILLANCE AIRCRAFT:

- It is a long-range maritime surveillance aircraft used for reconnaissance and anti-submarine warfare.
- Indian Navy inducted this maritime surveillance aircraft which took off from the Seattle facility of Boeing.
- P-8I would be armed with torpedoes, rockets, and missiles to fight against warships and for anti-submarine warfare.

AIRCRAFT CARRIER - (VISHAL)

- INS Vishal, also known as Indigenous Aircraft Carrier 2(IAC-2), is a planned aircraft carrier to be built by Cochin Shipyard Limited for the Indian Navy.
- It is intended to be the second aircraft carrier to be built in India after INS Vikrant(IAC-1), and the first supercarrier to be built in India.
- The proposed design of the second carrier class will be new, featuring significant changes from Vikrant, including an increase in displacement.
- An Electromagnetic Aircraft Launch System (EMALS) CATOBAR system is also under consideration.

4.9 SCORPENE SUBMARINES (PROJECT-75)

- The Scorpene-class submarines are a class of diesel-electric attack submarine jointly being developed by the French DCN and the Spanish company Navantia and now by DCNS.
- It features diesel propulsion and an additional air-independent propulsion (AIP) system.
- The state-of-art features of the Scorpene include superior stealth and the ability to launch an attack on the enemy using precision-guided weapons.
- The attack can be launched with torpedoes, as well as tube-launched anti-ship missiles, underwater or on the surface.
- Designed to operate in all theatres including the tropics, the submarines can undertake multifarious missions including anti-surface warfare, anti-submarine warfare, intelligence gathering, operations by special forces and mine laying, etc.
- The Scorpene is believed to be stealthier than the average submarine because of its advanced combat management system and low acoustic signature.

- It also uses a noise-canceling technique, whereby its equipment is mounted on elastic to prevent noisy vibrations from traveling outside the vessel.
- Its body is also designed to be more difficult for sonar to detect.
- **Kalvari is the first of Indian Navy's Scorpene-class stealth submarines being built under the Project 75**.

The following submarine is proposed to be developed under Project 75

- INS KALVARI
- INS KHANDERI
- INS KARANJ
- INS VELA
- INS VAGEER
- INS VAGSHEER

4.10 GHATAK

It is a new engine that will power India's first unmanned combat aircraft, or drones capable of delivering bombs as well as tackling aerial threats, as part of a project that envisages major participation of the private sector.

Ghatak will be a derivative of the abandoned Kaveri project that had been in the works for over two decades. The key difference in the current plan is the proposed participation of the private sector in a significant way.

The Indian UCAV (Unmanned Combat Aerial Vehicle) project is tentatively called Autonomous Unmanned Research Aircraft (AURA). The target is to get the system operational within eight years once the funds are cleared by the government. The original Kaveri project was meant to power the light combat aircraft but it got shelved as the engine could not deliver sufficient thrust for the fighter aircraft. In its revived avatar, the engine will be modified and its afterburners will be removed to power the first Indian UCAV.

DEFENSE SPACE RESEARCH ORGANISATION (DSRO)

- Recently Cabinet Committee on Security Clear The Proposal To Setup DEFENCE SPACE RESEARCH ORGANISATION To Promote India's Space Warfare Capacity

- It Will Be A Technical and Research Report organization to its parent agency The Defence Space Agency
- It will be headed by a senior different scientist who will lead a team of other scientists
- The Organisation Will Be Charged With finding and implementing defense applications for the entire spectrum of space technology.

CHAPTER 5: ENERGY IN INDIA

INTRODUCTION

With the electricity supply in Darjeeling in the year 1897, Power development in India commenced which was followed by commissioning of hydropower station at Shivasamudram in Karnataka.

The Ministry of Power is responsible for the development of electrical energy in India, and it is assisted in this endeavours by the Central Electricity Authority (CEA). Central sector power Corporations are entrusted with the construction and operations of generation and transmission projects under Central Sector that are namely; National Thermal Power Corporations(NTPC), National Hydroelectric Power Corporation Limited (NHPC), North-East Electric Power Corporation Limited (NEECL), Power Grid Corporation of India Limited (PGCIL).

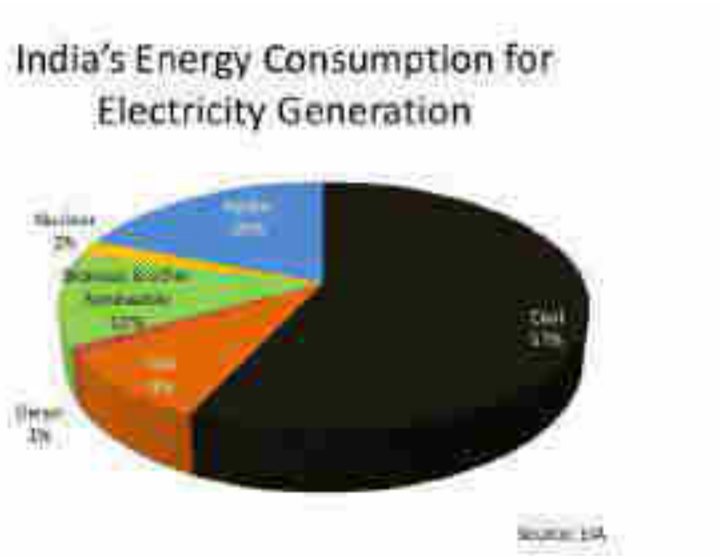
PGCIL is responsible for existing and future transmission projects in the central sector and also for the formation of the National Electricity Grid. Satluj Jal Vidyut Limited and Tehri Hydro Development Corporation are responsible for the execution of Nathpa Jhakri power project in Himachal Pradesh and Tehri Hydroelectric Power project in Uttarakhand while three statutory bodies:- Bhakra Beas Management Board (BBMB), BUREAU OF ENERGY EFFICIENCY, and Damodar Valley Corporation (DVC) are also under the administrative control of Ministry of Power.

The Rural Electrification Corporation (REC) is responsible for the development of electrical energy in rural areas while Power Finance Corporation (PFC), provides term finance to projects in the power sector. The autonomous bodies/societies such as the Central Power Research Institute (CPRI) and National Power Training Institute (NPTI) are also under the control of the Ministry of Power.

5.1 ENERGY POLICY OF INDIA

The energy policy of India is governed by the country's increasing energy deficit. Thus INDIA has increased focus on developing alternative sources of energy, particularly nuclear, solar and wind energy. By the year 2018, the primary energy consumption in India grew by 7.9%, and it is the third biggest after China and USA with 5.8% global share. The figures of net primary energy consumption from coal (452.2 Million Tonnes of oil equivalent), crude oil (239.1 million tonnes of oil equivalent), natural gas (49.9million tonnes of oil equivalent), nuclear energy (8.8 Mtoe), hydroelectricity (31.6 Mtoe) and renewable power (27.5 Mtoe) is 809.2 Mtoe (excluding traditional biomass use) in the calendar year 2018.

In 2018, the net imports from India were nearly 205.3 million tons of crude oil and its products, 26.3 Mtoe of LNG and 141.7 Mtoe coal totalling to 373.3 Mtoe of primary energy which is equal to 46.13% of total primary energy consumption. By 2030, India's dependence on energy imports is expected to exceed 53% of the country's total energy consumption. However, still, India is largely dependent on fossil fuel imports to meet its energy demands as around 80% of India's electricity generation is from fossil fuels. India has a surplus electricity generation capacity and thus is also a marginal exporter of electricity, as recorded in 2017. Since the end of the calendar year 2015, huge power generation capacity has been idling for want of electricity demand. With a production of around 210 Mtoe, India ranks second after China in renewables production.



<u>Fig 5.1: India's Energy Use By Sectors</u>

(IMAGE SOURCE: Rockwell industry ltd)

Due to rapid expansion of the energy market and growing demands India is expected to be one of the largest consumers of Energy by the year 2035 accounting for 18% of the rise in global energy consumption. Due to rise in the energy demand in India and Limited availability of fossil fuel resources India endeavours to ramp up its **Non-conventional energy** sources in order to meet energy demand of the country primarily from

- **Solar Energy**: 31 gigawatt (approx.)
- **Wind power**
- **Nuclear power:** India also tries to increase share of Nuclear power to 9% in total in the next 25 years

India has 5 nuclear reactors under construction in the world, the highest in the world while it plans to build additional 25 nuclear reactors.

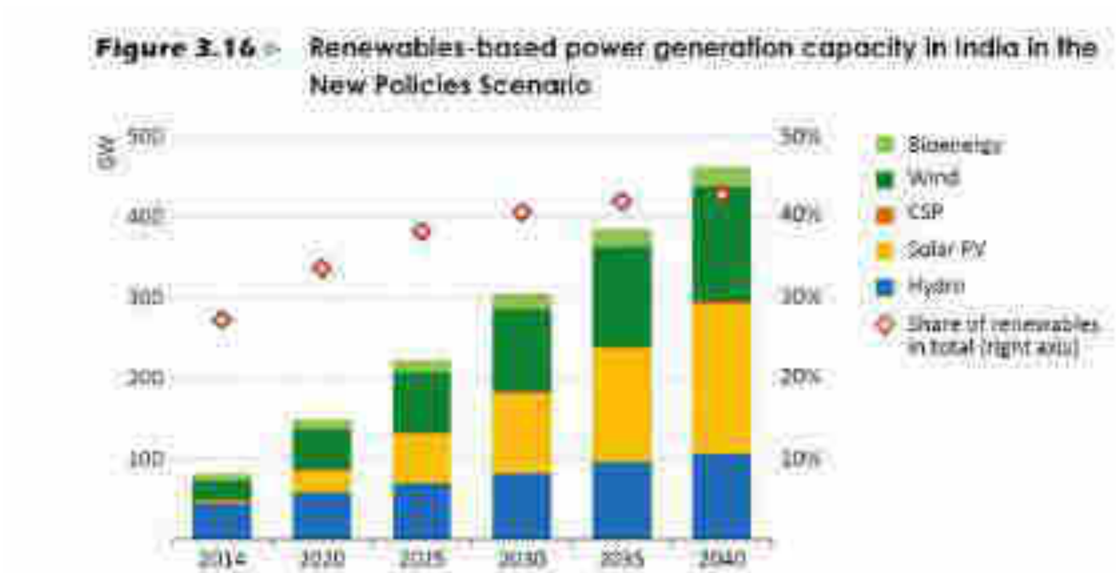


Fig: 5.2 Projected Renewable Energy sector Scenario

(image source:IEA)

5.2 CLASSIFICATION OF ENERGY SOURCES

Energy Resources are classified as all forms of fuels that can be used for developmental purposes in the modern world, either for heating, generation of electricity or for other forms of energy conversion processes. Energy resources can be roughly classified into three categories: **Renewable, Non-Renewable, and nuclear**.

The energy resources which are obtained from dead plant and animal deposits created over the long history of the planet are called FOSSIL ENERGY SOURCES. These resources are vast, but limited, and are not renewable.

Non-conventional or renewable energy are forms of energy that are naturally replenished on our planet. hydropower and biomass (e.g., plant fuels such as wood traditionally have been used throughout history, mostly for heating) are some Examples of traditional renewable resources. While examples of Modern renewable resources include wind, wave, tidal, solar, and geothermal. Some forms of fuels created from biomass (plants and animals) also fall under this category.

Nuclear energy resources are used as fuel for nuclear fission-based power plants. The amount of these rare radioactive elements is limited on our planet and cannot be replenished.

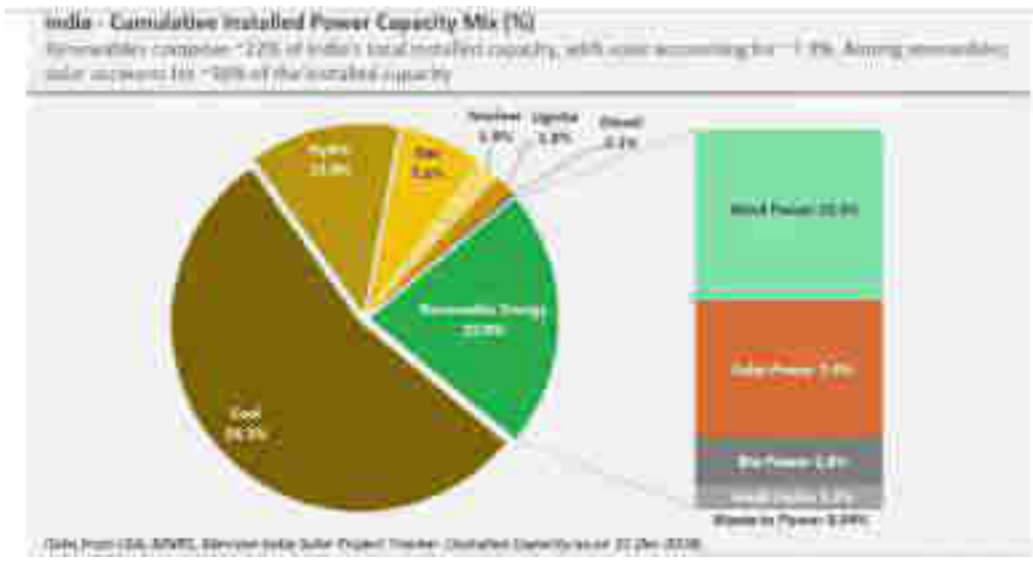


Fig:5.3 Total Installed Capacity (India)

(Image source: CEA)

5.3 INSTITUTIONS AND PROJECTS

Central Electricity Authority (CEA)

This organization was originally constituted under Section 3(1) of the Electricity (Supply) Act, 1948, which has been repealed and since substituted by Section 70 of the Electricity Act, 2003. It was established as a part-time body in 1951 and made a full-time body in 1975. The functions, responsibilities and duties of CEA are delineated in Section 73 of the Electricity Act, 2003.

The CEA advises the government on policy matters and formulates plans and reports for the development of electricity systems, projects, and other schemes related to the power sector. CEA prescribes the standards on matters such as the construction of electrical plants, electric lines and connectivity to the grid, installation and operation of meters and safety and grid standards under the Electricity Act 2003. this organization is also responsible for the concurrence of hydropower development schemes of central, state and private sectors and takes into consideration the factors which determine efficient development of the river and its tributaries for power generation, consistent with the requirement of drinking water, irrigation, navigation and flood control.

Ultra Mega Power Projects

The Ministry of Power, Government of India has taken steps to set up 9 ULTRA MEGA POWER PROJECT, each of 4000 Megawatt capacity in different states these projects are an initiative of Central electricity authority in Association with Power Finance Limited.

The first UMPP, developed by Tata Power in Gujarat (Mundra) has been commissioned and contributes 4,000 MW in power to the Western grid.

Sasan UMPP	Coal pithead (3600 MW)
Krishnapatnam UMPP	Coastal (4000 MW)
Mundra UMPP	Coastal (4000 MW)
Jharkhand UMPP	Coal pithead (4000 MW)

National Thermal Power Corporation (NTPC)

It is India’s largest energy conglomerate and has a history dating way back in 1975 to accelerate power development in India. Since then it has established itself as the dominant power major with presence in the entire value chain of the power generation business. it has forayed into generating electricity via hydro, nuclear and renewable energy sources, beginning initially from fossil fuels. This development will play a major role in lowering its carbon footprint by reducing harmful greenhouse gas emissions.

In May 2010 NTPC became a Maharatna company, one of the only four companies to be awarded this status. It is ranked No. 2 Independent Power Producer (IPP) in Platts Top 250 Global Energy Company Rankings.

The total installed capacity of NTPC stands at 62,110 MW (including JVs) own stations including 24 coal-based, 7 gas-based, 1 Hydro 1 Wind 11 Solar and 1 Small hydro plant. Under JV, NTPC has 9 coal-based, 4 gas based and 12 renewable energy projects. The capacity will have a diversified fuel mix and it is projected that by 2032, non-fossil fuel-based generation capacity shall make up nearly 30% of NTPC's portfolio.

In 2019, NTPC was recognized as "Laureate" for consistently ranking among "Top 50 Best Companies to Work for in India" for the last 11 years in the Great Place to Work and Economic Times survey. Besides, NTPC was also recognized as the best among PSUs and in Manufacturing.

5.4 NATIONAL HYDROELECTRIC POWER CORPORATION LIMITED (NHPC)

The NHPC (formerly known as National Hydroelectric Power Corp.) was incorporated on 7th November 1975 as Central Govt. Enterprise for development of Hydro Power in the Central Sector. Since it's inception the NHPC has become the largest central utility for hydropower development in India. It is mandated to plan, promote and organize an integrated and efficient development of power in all aspects deploying Conventional and Non-Conventional Sources in India as well as abroad.it is a Schedule 'A' Enterprise of Govt. of India and has been granted Miniratna status since 2008. It has an authorized share capital of Rs.15,000 crores.

To begin with, NHPC was assigned three most difficult and almost abandoned projects i.e. 180 MW Baira Siul in HP, 105 MW Loktak in Manipur and 345 MW Salal-I in J&K (now Union Territory of Jammu & Kashmir) from the erstwhile Central Hydroelectric Project Control Board. With the commissioning of Baira Siul in 1981, Loktak in 1983 and Salal-I in 1987, NHPC established its strong position in the hydropower sector of the country. Along the journey of over 44 years, NHPC's total installed capacity has reached 7071.2 MW from 24 projects including JV, Solar and Wind. During the financial year 2019-2020, NHPC Power Stations achieved the generation of 26121 MU.

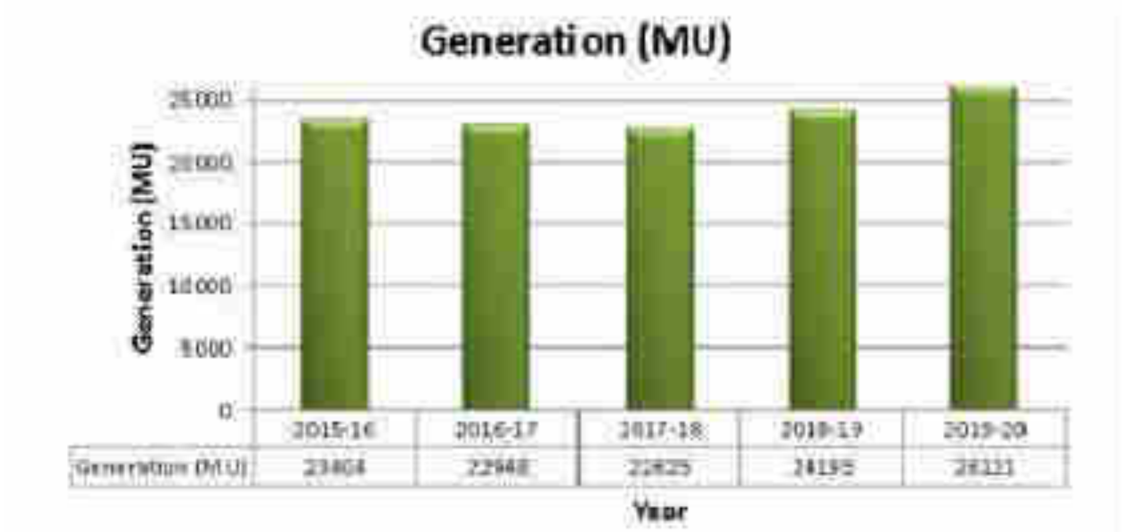


Fig 5.4 Power Generation from NHPC

(Image source: NHPC)

Presently NHPC is engaged in the construction of 6 projects aggregating to a total installed capacity of 4934 MW including 500 MW (Teesta-IV HE Project), 1000 MW (Pakal Dul HE Project) & 624 MW (Kiru HE Project) being executed through Subsidiary/ JV Company and 10 MW Floating Solar power Project in Kerala. Besides, 13 projects with an aggregate capacity of 8211 MW are under clearance stage which includes 7 Schemes of NHPC own, 4 in JV mode, 1 Wind Project & 1 Solar Project. Further, 2 projects with an aggregate capacity of 1079 MW are in the S&I stage.

Rural Electrification Corporation (REC)

Rural Electrification Corporation is a public Infrastructure Finance Company involved in India's power sector. It is a Public Sector enterprise engaged in financing and promotion of electrification projects across Rural India. It provides finances and loans to Central/ State Power Utilities in the country, Electricity Boards, Rural Electrification Cooperatives, NGOs and Private Power Developers.

In the year 2018, the Cabinet Committee of Economic Affairs gave its approval for the sale of 52.63% REC to the state-owned Power Finance Corporation Limited. While it was announced in March 2020 by the PFC that it intends to merge REC with itself.

Power Grid Corporation of India Limited (PGCIL)

PGCIL is an Indian state-owned electric utility company that is headquartered in Gurugram, India. About 50% of the total power generated in India on its transmission network is done by POWERGRID.

It is

- A “Maharatna” Central Public Sector Enterprise.
- Central Transmission Utility (CTU) of India
- India’s largest Electric Power Transmission Utility
- Listed Company since 2007
- Consistently rated “Excellent” under Memorandum of Understanding with Ministry of Power since 1993-94

National Grid and One Nation-One Grid

The Indian Power system is divided into five regional grids for planning and operational purposes. The integration of regional grids, and thereby establishment of National Grid, was conceptualized in the early nineties. The integration of regional grids which began with asynchronous HVDC back-to-back inter-regional links facilitating the limited exchange of regulated power was subsequently graduated to high capacity synchronous links between the regions.

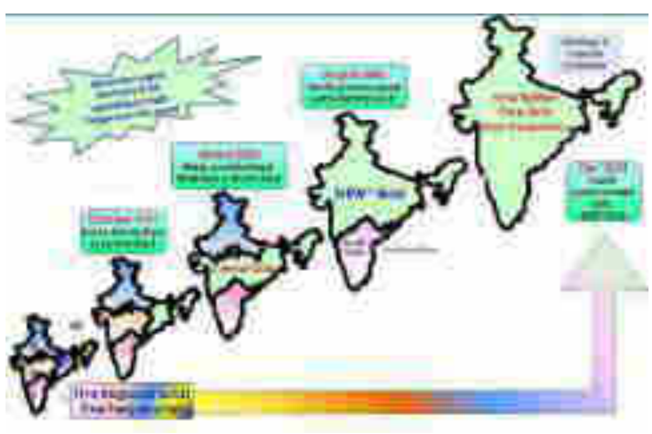
In the beginning, the inter-regional links were planned for the exchange of operational surpluses amongst the regions. But, later on, when the planning philosophy had graduated from Regional self-sufficiency to a National basis, the Inter-regional links were planned associated with the generation projects that had beneficiaries across the regional boundaries.

It is estimated that the country has a total inter-regional transmission capacity of about 75,050 MW, up till the end of the 12th Plan, which is expected to be enhanced to about 1,18,050 MW at the end of XIII plan.

Synchronization of all regional grids into one national grid will help in the optimal utilization of scarce natural resources by transfer of Power from Resource centric regions to Load centric regions. Moreover, this will facilitate the establishment of a vibrant Electricity market facilitating trading of power across regions. **One Nation One Grid shall connect all the regional grids and there will be one national frequency with asynchronous character.**

Grid management on a regional basis started in the sixties.

- Initially, State grids were interconnected to form regional grids, and India was demarcated into 5 regions namely Northern, Eastern, Western, North Eastern and Southern regions.
- In October 1991 North Eastern and Eastern grids were connected.
- In March 2003 WR and ER-NER were interconnected.
- August 2006 North and East grids were interconnected thereby 4 regional grids Northern, Eastern, Western and North Eastern grids are synchronously connected forming a central grid operating at one frequency.
- **On 31st December 2013, Southern Region was connected to Central Grid in Synchronous mode with the commissioning of 765kV Raichur-Solapur Transmission line thereby achieving 'ONE NATION'-'ONE GRID'-'ONE FREQUENCY'.**



<u>Fig 5.5 One Nation-One Grid</u>

(image source:cevgroup.org)

Power Finance Corporation

Incorporated on July 16th, 1986, Power Finance Corporation Ltd. is a Schedule-A Navratna CPSE, and is a leading Non-Banking Financial Corporation in the Country. PFC's registered office is located at New Delhi and regional offices are located at Mumbai and Chennai.PFC is under the administrative control of the Ministry of Power. PFC has conferred the title of a 'Navratna CPSE' in June 2007 and was classified as an Infrastructure Finance Company by the RBI on 28th July 2010.

PFC is the 8th highest profit-making CPSE as per the Department of Public Enterprises Survey for FY 2017-18. PFC is India's largest NBFC and also India's largest Infrastructure Finance Company.

Central Power Research Institute (CPRI)

Central Power Research Institute (CPRI) is the powerhouse of the Indian electrical industry. Set up in 1960 by the Government of India, it functions as a center for applied research in electrical power engineering assisting the electrical industry in product development and quality assurance. CPRI also serves as an independent authority for testing and certification of power equipment. CPRI's governing body includes eminent professionals from industries & utilities, prestigious academic and research institutions & the government. It employs over 300 highly qualified and experienced engineers & scientists besides other supporting staff. With its state-of-the-art infrastructure and expertise, CPRI has made significant contributions to the power sector in the country for improved planning, operation and control of power systems. Besides in-house R&D, CPRI also undertakes sponsored research projects from manufacturers and other agencies in different areas of specialization.

North East Electric Power Corporation Limited (NEEPCO)

(NEEPCO is a schedule-A 'MINI RATNA' Category-1 and is a central public sector enterprise that is owned by the Government under the MINISTRY OF POWER. The NEEPCO was formed on 2nd April 1976 to plan, investigate, design, construct, generate, operate and maintain power stations in the Northeast East region of the country.

National Thermal Power Corporation Limited overtook the NEEPCO in the year 2019 and now works as its Subsidiary.

Bureau of Energy Efficiency (BEE)

The Bureau of Energy Efficiency (BEE) was set up on 1st March 2002 under the provisions of the Energy Conservation Act, 2001. Its mission is to assist in developing policies and strategies with a thrust on self-regulation and market principles, within the overall framework of the Energy Conservation Act, 2001 with the primary objective of reducing the energy intensity of the Indian economy.

Role of BEE

BUREAU OF ENERGY EFFICIENCY coordinates with designated consumers, designated agencies and other organizations and recognizes, identifies and utilizes the existing resources and infrastructure, in performing the functions assigned to it under the Energy Conservation Act. BEE has been provided regulatory and promotional functions under the act.

The Major Functions of BEE include

- Creating awareness and dissemination of information on energy efficiency and conservation
- Arranging and organizing training of personnel and specialists in the techniques, to sensitize them on efficient use of energy and its conservation
- Strengthening consultancy services in the field of energy conservation
- To Develop testing and certification procedures and promote testing facilities
- Formulate and facilitate the implementation of pilot projects and demonstration projects
- Promote the use of energy-efficient processes, equipment, devices and systems
- BEE seeks to promote innovative financing of energy efficiency projects
- It provides monetary assistance to institutions for promoting the efficient use of energy and its conservation.
- Preparing educational curriculum on efficient use of energy and its conservation
- Implement international co-operation programs relating to the efficient use of energy and its conservation.

5.5 CONVENTIONAL ENERGY SOURCES (PRODUCTION AND CONSERVATION)

Petroleum and Natural Gas

The Ministry of petroleum and natural gas is entrusted with the responsibility of exploration and production of oil and natural gas as well as the import of LNG. It is also involved in refining, production, marketing, distribution, import and export of petroleum products. India is a member of the International Energy Forum which is a platform for dialogue between petroleum producing and consuming countries. It's headquartered in Riyadh, Saudi Arabia.

Petrol Consumption Growth since FY10

Financial Year	Petrol Consumption (000) tonne	Growth (%)
FY10	128,18	—
FY11	141,92	10.71
FY12	149,91	5.64
FY13	157,44	5
FY14	171,28	8.79
FY15	190,75	11.36
FY16	218,47	14.53
FY17	237,65	8.77
FY18	261,74	10.13
FY19	282,84	8.06

Source: PPAC

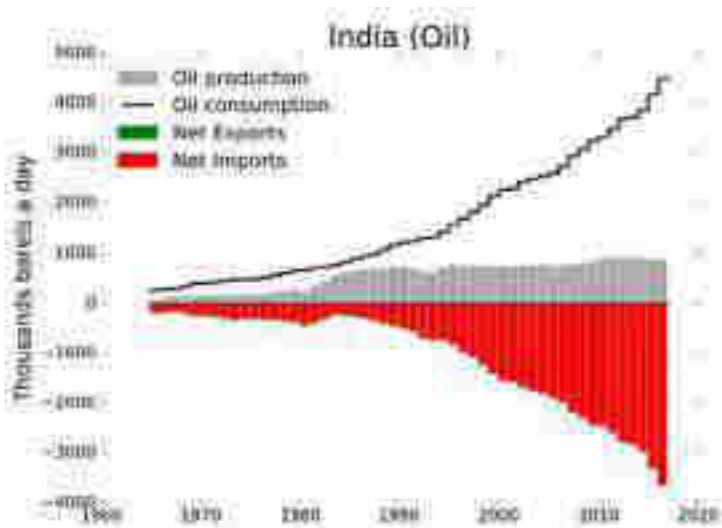
Petroleum Consumption

Financial Year	Total Gas Production	Change (%)	Offshore Production	Onshore Production
2011-2012	47.55	(8.92)	38.47	9
2012-2013	40.67	(14.46)	31.80	8.87
2013-2014	35.40	(13)	26.39	9.01
2014-2015	33.65	(5)	24.86	8.79
2015-2016	32.24	(4.19)	23.01	9.23
2016-2017	31.89	(1.08)	22.03	9.85
2017-2018	32.64	2.35	22.01	10.63
2018-2019	32.87	0.63	22.11	10.75

All Figures in Billion Cubic Meter (BCM)

Source: Ministry of Petroleum and Natural Gas (MoPNG)

5.6 GAS PRODUCTION IN INDIA



Oil production and consumption over the years

Oil and Natural Gas Corporation (ONGC) and Oil India Limited (OIL) as well as private and joint venture companies are involved in exploration and production of Oil and Natural Gas in the country.

Oil and Natural Gas Corporation Limited (ONGC)

ONGC is an Indian Crude Oil Gas Corporation involved at national and multinational level.The registered office of ONGC is in New Delhi. It is a state-owned enterprise under the administrative control of the Ministry Of Petroleum and Natural Gas . ONGC is the largest Oil and Gas exploration and production company in the country which produces around 70% of India's Crude oil resources (around 57% of the country's total demand) andupto 84% of its Natural Gas resources . ONGC was given the Maharatna status by the Government In November 2010

ONGC Videsh Limited is The international Subsidiary of ONGC .ONGC Videsh Limited participates in various exploration and production projects abroad, and currently has projects in 17 countries, which makes it one of the largest multinational Corporation of the world.

5.7 CONVENTIONAL MINERAL RESOURCES OF INDIA

Coal

Coal is the main source of energy in India and accounts for around 2/3rd of the country's requirements for commercial purposes. There are four varieties of coal found in India that is: Anthracite, Bituminous, Lignite and Peat.

Note: Gondwana coal makes up around 98 per cent of the total reserves and 99 per cent of the production of coal in India While lignite comes under the category of Tertiary coal.

Coal is the base of 70% power generation in the country. Indian coal has high ash content and low Sulphur content. India has one of the largest coal reserves, but we are importing large coal for billion dollars because we choose a monopoly that is incapable of domestic demand. To overcome this, we went for captive mining, but this will have a big impact on Coal India and the state which has coal Reserves.

India's Coal Production was reported at 308.044 TOE mn in Dec 2018. This records an increase from the previous number of 286.556 TOE mn for Dec 2017. India's Coal Production data is updated yearly, averaging 149.832 TOE mn from Dec 1981 to 2018.

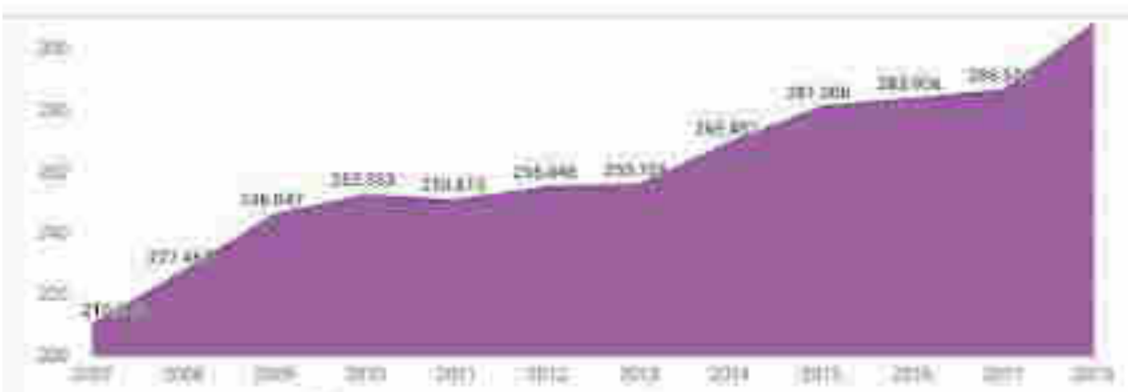


Fig: 5.6 Coal Production over the years

(Image source: CEIC)

Uranium

Uranium is one of the heavy metals that can be utilized as a rich source of concentrated energy. The element exists in many rocks in the concentration of 2 to 4 ppm(parts per million) and common in Earth's crust as tungsten and tin. It also exists in seawater and can be retrieved from the oceans.

Uranium was formed over 6.6 billion years ago. Though it is not common in the solar system, its slow radioactive decay provides a major source of heat within the Earth, responsible for continental and convection drift. Uranium's high density means it also has applications in the counterweights of aircraft control surfaces and radiation shielding. It is one of the heaviest among all the naturally occurring elements when arranged based on the increasing mass of their nuclei on a scale. The element is 18.7 times denser than water.

Uranium exists in various slightly different forms known as 'isotopes.' These isotopes are distinct in the number of uncharged particles in the nucleus. Natural uranium was found as a mixture of two isotopes. U-238 accounts for 99.3% and U-235 around 0.7%.Pure uranium is silver in colour and readily oxidizes in air.

It is also used to colour glass that glows greenish-yellow in black light, not due to radioactivity because the glass itself is a bit radioactive. The fluorescence is because of the UV light that excites the uranyl compound in the glass and makes it let off photons when it settles down.

Note: India has no significant reserves of uranium. All needs are met through imports. India imports thousands of tonnes of uranium from Russia, Kazakhstan, France.

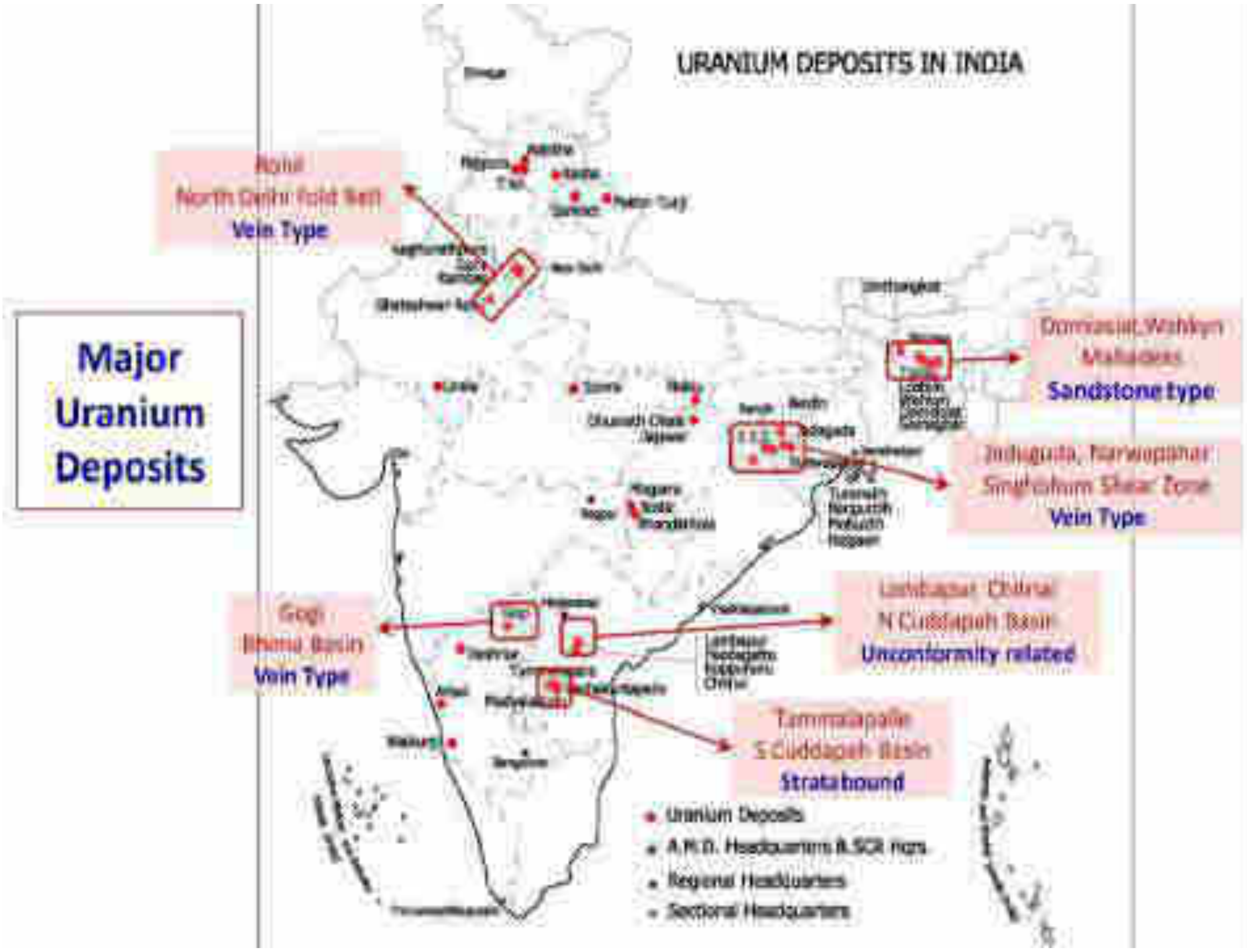


Fig 5.7 Uranium Deposits in India

(Image source: Mines. gov.in)

Thorium

India has the World's Largest Thorium Reserves and has modest uranium reserves. Thorium, despite its greater abundance in nature and a number of superior characteristics, lags behind use of uranium as it does not have any fissile content. The fertile thorium-232 has to be converted into uranium-233 first for use in a nuclear reactor. **Considering the country's vast thorium resources, the long-term nuclear energy policy of India has been focused on utilization of thorium early on.** A three-stage nuclear power program was drafted already in the 1950's.

The known reserves of thorium in India are estimated to be between 457,000 and 508,000 tonnes and mostly located along the **Eastern Coastal Belt**. Kerala, Jharkhand, Bihar, Tamil Nadu and Rajasthan are the main producers.

Fig 5.8 Thorium Deposits

(image source:researchgate)

Monazite

It is a reddish-brown phosphate mineral that contains rare-earth elements. Due to variability in composition, monazite is considered a group of minerals.Monazite is an important ore for thorium, lanthanum, and cerium. It is often found in place deposits everywhere. Three countries **INDIA MADAGASCAR**, and **SOUTH AFRICA** have large deposits of monazite sands. India has a large number of deposits of MONAZITE.

Atomic Minerals Directorate for Exploration and Research (AMD), under the Department of Atomic Energy (DAE) has estimated the potential of around 11.93 million tonnes of monazite resources in the beach sand mineral placer deposits along the coastal region of India. It is projected that Monazite contains about 55 – 60% total Rare Earth Oxide. The state-wise resources of in situ monazite established by AMD so far are as follows:

State	Monazite (Million tonne)
Odisha	2.41
Andhra Pradesh	3.72
Tamil Nadu	2.46
Kerala	1.90
West Bengal	1.22
Jharkhand	0.22
Total	**11.93**

<u>Fig 5.9 State wise Monazite Deposits</u>

(source:MINISTRY OF MINES)

It has been found that the quantity of xenotime resources, another rare-earth bearing mineral, are negligible in India. AMD has established about 2000 tonnes of xenotime-bearing heavy mineral concentrate containing 2% xenotime in the riverine heavy mineral placer deposits of Chhattisgarh and Jharkhand.

Monazite is a mineral mainly containing rare earths and thorium-a prescribed substance to be handled by the Department of Atomic Energy (DAE). Accordingly, Indian Rare Earths Ltd. (IREL) which is under the administrative control of the Dept. of Atomic Energy (DAE) and wholly owned subsidiary of GOVERNMENT, utilises monazite mainly for production of rare earth compounds, and thorium, as needed in the Department of Atomic Energy.

5.8 RARE EARTH MINERAL

As defined by IUPAC, **rare earth minerals are a set of seventeen chemical elements in the periodic table, specifically the fifteen lanthanides, as well as scandium and yttrium**. Scandium and yttrium are considered rare earth elements because they tend to occur in the same ore deposits as the lanthanides and exhibit similar chemical properties. They are not especially rare, but they tend to occur together in nature and are difficult to separate from one another.

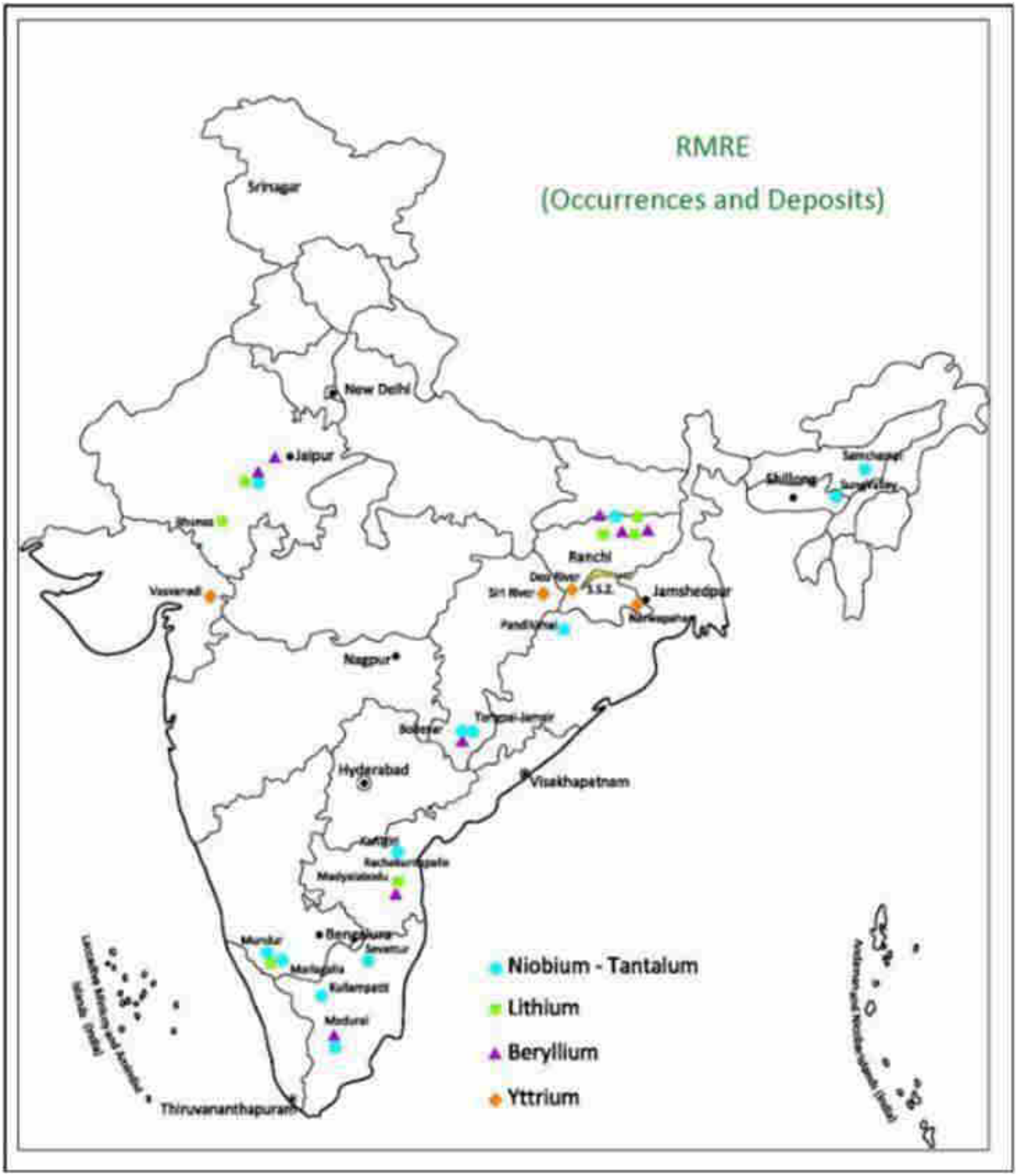


Fig 5.10: Rare earth minerals deposits (India)

(Image source: Atomic Energy Directorate)

India has the third-largest reserves of rare earth minerals in the world. Indian Rare Earths Ltd under the Department of Atomic Energy is the sole producer of rare earth compounds.

Globally, China has a monopoly over rare earths, after USA's recede in this industry due to serious environmental and health concerns. China had once almost shivered the Japanese economy by halting the export of rare earth elements. India is also blessed with some crucial rare earth minerals like zirconium, neodymium etc., available in plenty in monazite sands. This could contribute to Indian export markets if utilized properly.

However, Owing to various reasons such as cost reduction due to high production (economies of scale) in China, lack of demand in the domestic market, lack of domestic processing technologies, the production of rare earth minerals has depleted over the years. Most of the products that use rare earth minerals as raw materials are imported. Despite rare earth minerals having high value add the potential for export growth, inadequate processing technologies have made India suffer.

Rare earth minerals are very crucial for India to reduce the energy burden. It is an important component in the manufacture of hybrid vehicles, fuel cells and LEDs.

Fig: 5.11 Rare Earth Minerals

(Image source: Deccan Chronicle)

5.9 RENEWABLE ENERGY (NON CONVENTIONAL ENERGY SOURCES)

India is blessed with plenty of responsible energy sources like solar wind hydro and Biomass the importance of renewable energy was recognised in the country as early as 1970 the ministry of non conventional energy sources is the nodal Ministry of the government for all matters relating to new and renewable energy systems and devices marketing outlets namely **Akshay Urja shops** have been set up in a number of major cities and towns with a view to promote sales servicing and repair of these systems and devices Prime Minister of India release the national Action Plan on climate change(NAPCC) in 2008 which proposes to start 8 missions which are as follows :

Fig 5.12: Missions Under NAPCC

(Image source: http://ndias-national-action-plan-on-climate.html?m=1)

Subsequently many States had also formulated their own State Action Plan on climate change. According to a report in 2016 by REN21, the global energy consumption by the use of renewable energy resources contributed to 19.2% in 2014 and 23.7% in 2015. Many countries have started to invest in these renewable energy resources as these resources will help in maintaining a sustainable development. The amount of investment in 2015 was about 286 billion dollars and major sectors were biofuel, solar power, wind, and hydroelectricity.

The existence of renewable energy resources is spread over a wide geographical area in comparison to the conventional energy resources which are often concentrated to a limited number of countries like oil and gas are mostly concentrated in the Middle East countries. The use of renewable energy resources in energy generation is resulting in less pollution and has a significant effect on economic benefits and energy security.

We can define renewable energy as those energies which can never be depleted. The importance of renewable energy is invaluable. These types of energy sources are different from fossil fuels, such as oil, coal, and natural gas. Some examples of renewable energy sources are:

- **Wind energy**
- **Solar energy**
- **Geothermal energy**
- **Hydropower**
- **Biomass energy**
- **Tidal Energy**
- **Hydrogen and Fuel cells**

The sources could sustain for a longer period of time and can easily be renewed often. Sustainable sources are biomass, nuclear power, geothermal, wind energy, solar power, tidal power, and wave power. The sources of renewable energy are known to be less polluting and therefore the whole world is looking forward to new carbon emission norms, where carbon will play a major role in developing new factories and industries. They will be rated according to the carbon emission and the products that they are producing will be rated accordingly.

India has outlined its Intended Nationally Determined Contributions as per the Paris Accord on Climate Change, and made a pledge that by 2030, around **40% of its installed power generation capacity shall be from non-fossil fuel sources and also by 2030, reduce emission intensity of GDP by 33-35 % from 2005 level**. Economic growth, increasing prosperity, a growing rate of urbanisation and rising per capita energy consumption has increased the energy demand of the country.

Keeping in view the above and our commitment for a healthy planet with less carbon intensive economy, we decided in 2015 that **175 GW of renewable energy capacity will be installed by the year 2022. This includes 100 GW from solar, 60 GW from wind, 10 GW from biomass and 5 GW from small hydro power**. The substantial higher capacity target will ensure greater energy security, improved energy access and enhanced employment opportunities, India will become one of the largest Green Energy producers in the world. With the accomplishment of these ambitious targets, and would even surpass several developed countries.

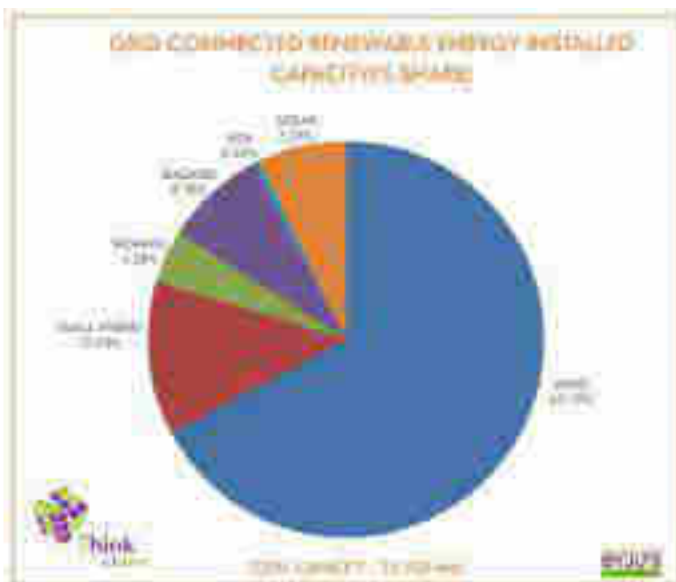


Fig 5.13 Installed Capacity of Renewables

(Image source: Byjus)

The Prime Minister in his address atto Climate Action Summit stated that “India’s renewable energy capacity would be increased to much beyond 175 GW, and later till 450 GW”.In line with the objective of expanding renewable energy sector, several important initiatives were taken during year 2019.

5.10 SOLAR ENERGY

The radiant light and heat energy from the sun is harnessed with the use of solar collectors. These solar collectors are of various types such as the photovoltaics, concentrator photovoltaics, Solar heating (CSP) concentrated solar power, artificial photosynthesis, and solar architecture. This collected solar energy is then used to provide light, heat and different other forms of electricity. India, is a tropical country, thus It experiences about 300 sunny days in a year (approximately).

The total solar energy received by India in a year = 5000 trillion kilowatt-hours (kWh)- that is equal to 4-7 kWh per square meter per day. According to the **Ministry of New and Renewable Energy**,India has a potential of generating more than 750 GW of solar power (close to 68 % of its renewable energy potential).

The technology that is generally utilised for Solar Energy generation are:

Solar Thermal Technology(Solar Thermal Energy Programme)	Solar Photovoltaics
These technologies utilise sunlight reflectors and concentrators in order to either convert the solar heat into electricity or use the heat energy for domestic and commercial heating purposes. Water is turned into steam by the solar heat, which can be used to run the turbines, producing alternating current (AC) power.	Photovoltaic cells (PV) convert the incident sunlight into electricity which is called the photoelectric effect. The Solar Photovoltaics cells are made of semiconducting materials like silicon, cadmium telluride,carbon-rich polymers etc. Among these, silicon-based and cadmium telluride based cells are the most used as PV cells . These cells convert solar energy into direct current (DC)

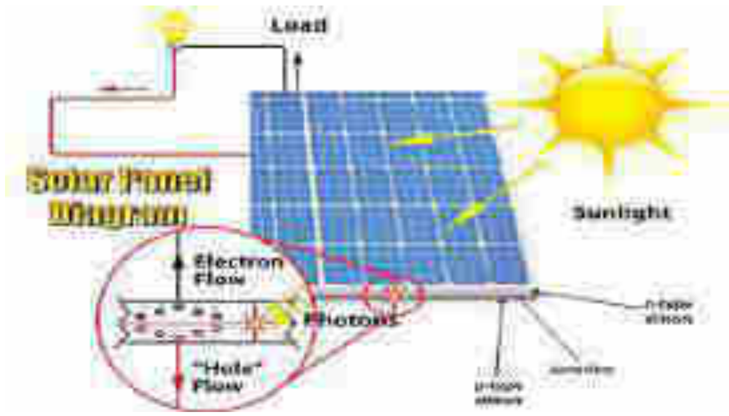


Fig 5.14 Solar Panel

(Image source: byjus.com)

The Government of India has set a national target of installing 1,00,000 MW grid connected solar power capacity in the country by December, 2022. As on 31.10.2019, a total grid connected solar power generation capacity of 31,696 MW has been set up in the Country, projects of 17998 MW capacity are at various stages of installations and tenders for 36278 MW capacity projects have been issued. With new tenders of around 15000 MW planned in the remaining period of 2019-20 and 2020-21, we are on course for achieving the target.

The Union Government has been implementing the National Solar Mission under which various Schemes have been launched for promoting the generation and use of solar power in the country. This apart, the Ministry of New and Renewable Energy makes publicity for effective implementation of all schemes including Solar Schemes through print, social, electronic and other media. The Ministry has also launched a Mobile App for solar rooftop systems.

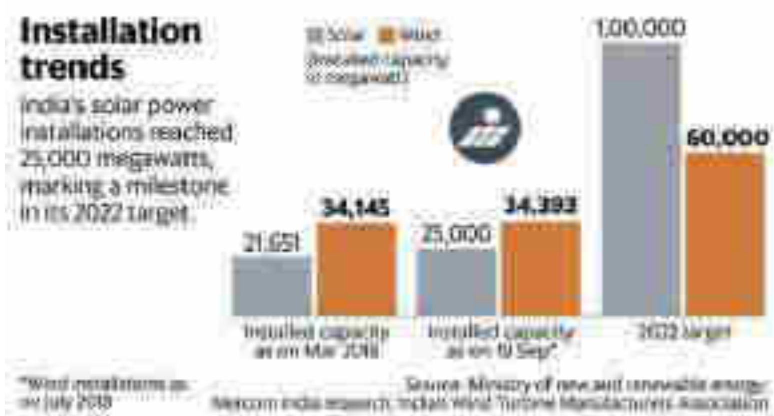


Fig: 5.15 Installed Solar Capacity

(Image source: Mercom india and MNRE)

National Solar Mission

Initially in India, the focus on solar technologies was bordered on the social and rural segment. Some institutes like IIT, National Physical Laboratory focused on developing solar, thermal and photovoltaic (PV) technologies. PV technology was being promoted extensively to meet the challenge of providing electricity for rural telecom networks, village electrification and electrification of the unmanned railway crossing.
Jawaharlal Nehru National Solar Mission is also known as the National Solar Mission. The mission was launched in Jan 2010 by the Government.

The Target for National Solar Mission:

- It had set a target of 20,000 MW of grid-connected solar power by 2022. It was revised in June 2015 to 1,00,000 MW by 2022.
- The 100 GW solar power capacity has been divided into:
    - Rooftop solar electricity generation – 40 GW
    - Large and Medium Scale grid-connected solar projects – 60 GW

Funding:

- The total cost for up-gradation to 100 GW solar power capacity would be $ 94 Billion.
- The Central Government is also planning to leverage bilateral and international donors, including green climate funds under the United Nations Framework Convention on Climate Change (UNFCCC).
- Using the bundling mechanism with thermal power.
- Investments would come from large Public Sector undertakings.
- Funds would be generated from Independent Power Producers.
- The Government of India is providing Rs 15,050 crore as capital subsidy to promote solar capacity addition.
- This capital subsidy is for rooftop solar projects in various cities and towns, for viability gap funding based projects to be developed through the Solar Energy Corporation of India (SECI) and for decentralised generation through smaller projects.

The mission is made up of 3 phases:

- Phase 1 – 2012 – 13
- Phase 2 – 2013 – 17
- Phase 3 – 2017 – 22

Targets are given Below:

- Install 1,00,000 MW of solar power by 2022.
- 40 GW rooftop and 60 GW through large and medium scale grid-connected solar power projects.
- To achieve 15 million sq metres of solar thermal collector area by 2017 and 20 million by 2022.
- To deploy 20 million solar lighting systems for rural areas by 2022.

Implementation model:

- Bundling scheme

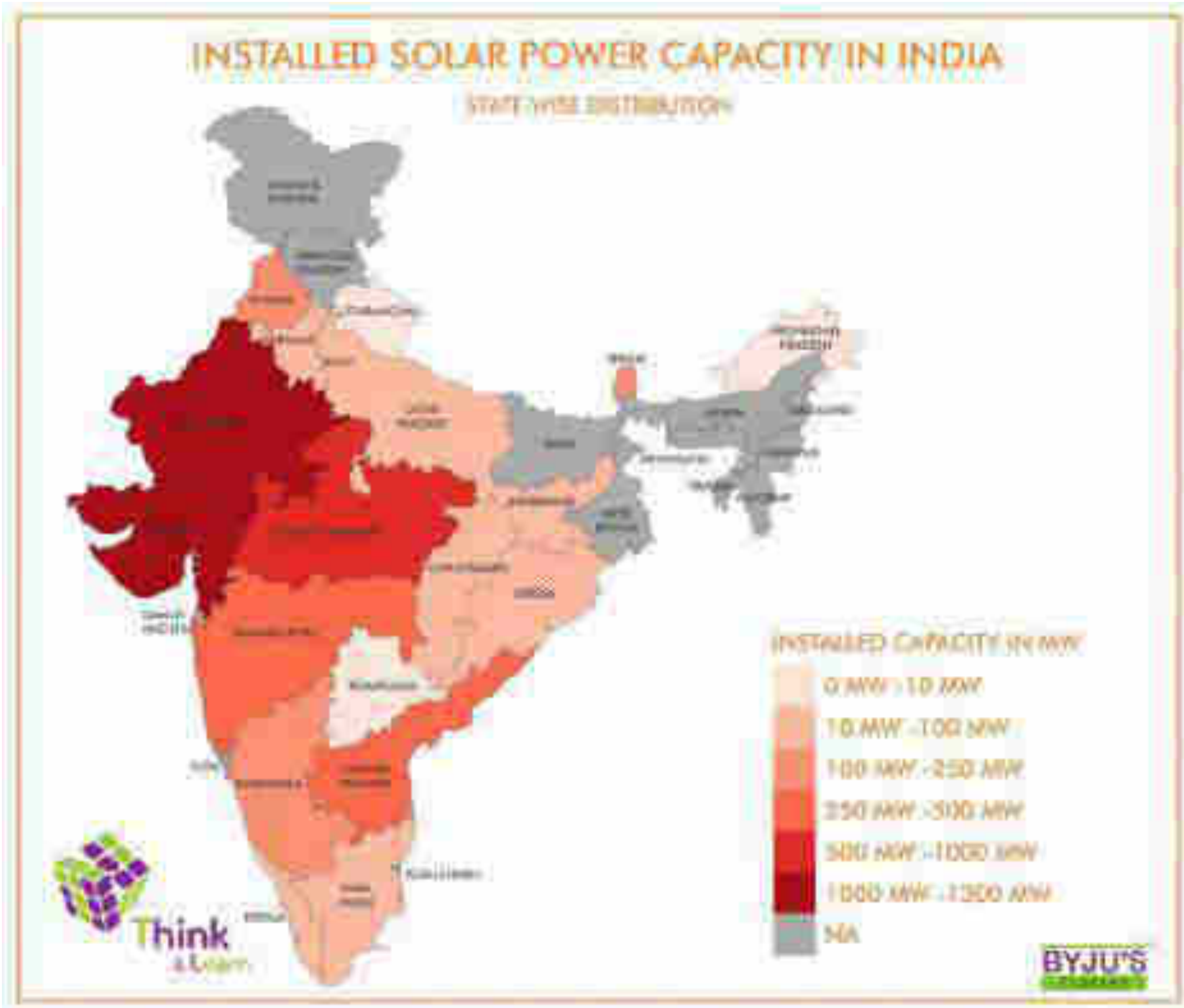
- Generation Based Incentive (GBI) Scheme
- Viability Gap funding scheme

The mission also aims to reduce the cost of Solar Power Generation in the country through

- Long term policy
- Large Scale deployment goals
- Aggressive R&D
- Domestic production of critical raw materials, components and products, as a result, to achieve grid tariff by 2022.

Achievements of the National Solar Mission:

- To reduce the risks of solar power producers, Solar Energy Corporation of India (SECI) was established as a major procurement agency.
- Creation of larger projects to bring down capital investments in solar power generation projects through the development of integrated solar parks so as to provide infrastructure for solar power plants.
- Renewable energy corridor was also launched to develop a dedicated transmission grid for areas with an abundance of sunlight or wind to create solar and wind energy.
- Solar radiation monitoring stations were set up across India.



Major Positive Developments since 2014

The new Government as per its ambition to provide electricity for all, the target was revised for establishing grid-connected solar power was revised from 20 GW to 100 GW under the NSM.

The huge quantum jump in targets generated huge demands for solar energy projects and equipment.

100 GW is divided into two major segments –

a) 60 GW of grid-connected ground-mounted large solar power plants, typically above 1 MW capacity.

b) 40 GW of rooftop solar power plants for generation of electricity.

The emphasis is on roping in Central and State Public Sector companies, defence establishments and others who started establishing projects on their unutilized land. The problem of limited land availability can be avoided using innovative ideas such as floating solar power plants, solar power plants over canals, and use of barren land for solar power plants are being promoted. Revised targets for Renewable Purchase Obligations (RPO), to ease the purchase of solar power, net metering, interstate power purchase by bulk consumers such as Delhi Metro. Focus on skill development and indigenous manufacturing through the establishment of Skill council for green jobs.

Advantages of Solar Energy:

Advantages of solar energy are:

1. **Clean**: It is considered to be the cleanest form of energy as there is no emission of carbon dioxide like in case of fossil fuels which is one of the causes of global warming.
2. **Renewable**: There is an ample amount of energy available on earth as long as the sun exists.
3. **Reliable**: The energy can be stored in the batteries and so there is no question of unreliability.
4. **Reduction in utility costs**.
5. **Free energy** because it can be trapped easily.

Disadvantages of Solar Energy:

1. The production is low during winters and on cloudy days.
2. Installation and the initial cost of the materials are expensive.
3. Space consumption is more.

Due to several efforts made by the Government, a report of 2018 by the International Renewable Energy Agency, stated that India is now the lowest-cost producer of solar power globally.

Some Initiative to Promote Solar Power Generation in India

(a) Solar Cities Programme:

The Ministry of New and Renewable Energy is implementing a programme on 'Development of Solar Cities' which aims to reduce a minimum of 10% of the projected demand of conventional energy of the city through renewable energy installations and energy efficiency measures. Around 60 cities will be developed under this.

(b) Solar Energy scheme for Small powerloom Units:

Government has approved a new scheme to provide financial assistance/capital subsidy to small powerloom units, for installation of Solar PhotoVoltaic (SPV) plant, in order to alleviate the problem of power cut/ shortage faced by decentralized powerloom units in the country.

Under the Solar Energy Scheme, the plants have two options:

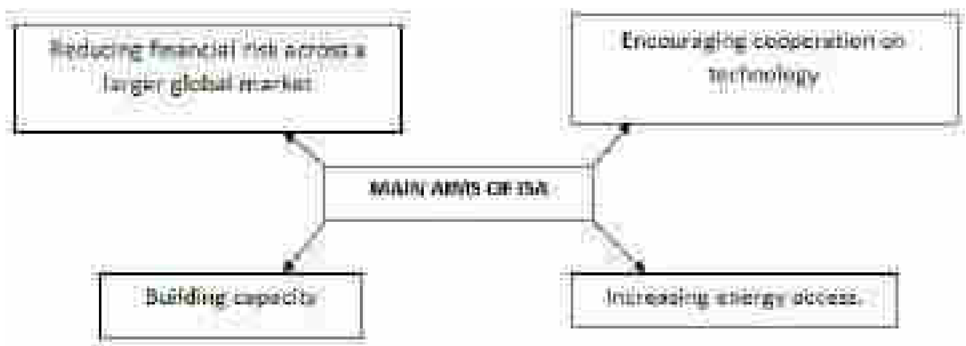
- On-Grid Solar Power Plant where power cut/shortage is negligible and power tariff is high
- Off-Grid Solar Power Plant in areas where there is power shortage & on-grid power is not continuously available.

(c)International Solar Alliance (ISA):

The International Solar Alliance is a group of nations that lies within the Tropics (Tropic of Cancer and Tropic of Capricorn) and receive sunshine for more than 300 days.

- It is a platform for the collective collaboration of sunshine countries in the domain of energy security.
- The energy that comes from the Sun in a day is enough for the entire globe to use for a whole year, however, we are not able to capture the entire energy that comes.
- Most of the sunshine countries are poor and the least developing. Hence, solar power becomes critical for their energy security.
- The underlying rationale for ISA is to “ensure access to affordable, reliable, sustainable and modern energy for all”,
- It also plans to increase the share of renewable energy substantially by 2030. By 2030, it envisages enhancing international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology.

- Developing solar projects in silos is not financially viable, despite the involvement of prominent financial institutions such as AIIB, World Bank, NDB and private and public investments towards this.
- Absence of established renewable energy policy.
- There is no ecosystem that creates a willingness to buy and set up renewable energy; there is no proper integration method with conventional energy.
- Hence, the focus of ISA will be on policy, ecosystem and integration with regard to solar energy.



(d) KUSUM Scheme:

Kusum Scheme is being implemented by- The Ministry of New and Renewable Energy	Initially, the government will distribute 1.75 million off-grid agricultural solar pumps	10000 MegaWatts Solar plants will be put up on lands that are barren.
The state electricity distribution companies, also called, DISCOMS will buy the additional solar power produced by the farmers on barren lands. DISCOMS will get sops to buy this electricity.	Tube wells and existing pumps of the government will be converted to run on solar power	Farmers will get a subsidy of 60% on solar pumps. It shall be deposited to their bank accounts directly. This subsidy is going to be shared by the central and the state governments. 30% of the cost will be obtained as a bank loan. Hence, only the 10% will have to be borne by the farmers themselves.

(e) Grid-Connected Rooftop Solar (RTS) Programme:

Phase II of the Grid connected rooftop solar programme was approved with a target for achieving cumulative capacity of 40,000 MW from Rooftop Solar (RTS) Projects by the year 2022 in February 2019.

(f) Government Producer Scheme for setting up Solar PV Power plants using domestically manufactured SPV cells & modules:

Government have approved a Scheme [CPSU Scheme Phase-II (Government Producer Scheme)] for setting up of solar PV power plants by Government Producers [Central Public Sector Undertakings (CPSUs)/ State Public Sector Undertakings (SPSUs)/ Government Organisations, etc.], as per extant Guidelines, in a World Trade Organization (WTO) compliant manner, using domestically manufactured solar PV cells and modules to encourage 'Make in India' in Solar PV Manufacturing sector.

(g) Wind-Solar Hybrid:

- The main objective of the **National Wind-Solar Hybrid Policy** is to provide a framework for promotion of large grid connected wind-solar PV hybrid systems for optimal and efficient utilization of wind and solar resources, transmission infrastructure and land.
- The wind - solar PV hybrid systems will help in reducing the variability in renewable power generation and achieving better grid stability.
- The policy also aims to encourage new technologies, methods and way-outs involving combined operation of wind and solar PV plants.
- So far, Solar Energy Corporation of India (SECI) has awarded 1440 MW capacity of wind solar hybrid projects after e- reverse auction.
- In addition, Hero Future Energies has commissioned a wind solar hybrid project by adding 28.8 MW of solar project to an existing 50 MW wind project (Total 78.8 MW hybrid project) in Raichur district, Karnataka.

(h) Solar Parks Scheme:

The Ministry of New and Renewable Energy (MNRE) has launched a scheme to set up several solar parks across various states in the country, each with a capacity of Solar Projects generally above 500 MW.

The Scheme proposes to provide financial support by the Government of India to establish solar parks to facilitate the creation of infrastructure necessary for setting up new solar power projects in terms of allocation of land, transmission and evacuation lines, access roads, availability of water and others, in a focused manner.

Solar Energy Corporation of India (SECI), a central public sector enterprise under MNRE, has been implementing various schemes to develop the solar sector in the country. As per the policy, these solar parks will be developed in collaboration with the State Governments.

Some of the biggest solar power projects in INDIA include:-

- Pavagada solar park(Karnataka), it is the largest
- Kamuthi solar park (Tamil Nadu)
- Bhadla solar park(Rajasthan)
- Rewa ultra mega solar park (MP)

The implementation agency would be the Solar Energy Corporation of India (SECI) on behalf of the Government of India (GOI). SECI handles funds that are made available under the scheme on behalf of the Government Of India. Under the scheme, the states designate a nodal agency for the implementation of the solar park.

Issues with the Solar Parks:

Several concerns have been rising out of the establishment and working of Solar Parks, primary among which is the generation of Waste out of the plants which have been flagged by Farmers and communities living in the vicinity of these parks

One Stark example of this is the issues arising due to the Pavagada solar park in Karnataka, where farmers and Civil Society have raised problems of waste generation and unprecedented dumping of unused parts from the plant.

Also, the acquisition of land from farmers on lease has not only resulted in irrational land-use changes to the fertile lands but the majority of greenery and tree cover has been cleared off the lands instead of setting up parks. There have been claims that Solar Parks has only helped big farmers as small and marginal farmers only get a meager amount in return for the lease entered into.

Moreover, a large amount of polluting gases released due to the burning of waste is causing a lot of problems for the people in the surrounding areas. So also studies are highlighting that the temperature of villages where the solar parks are being established is comparatively higher due to the reflection of light by the solar panels.

Atal Jyoti Yojana (AJAY) Phase-II

- A scheme for installation of Solar Street Lights.
- Financial support: 75% of the cost by MNRE and balance 25% through MPLAD.
- Targets: A total of 3,04,500 Solar Street Lights (SSLs) will be installed

Wind Energy

The energy we get from winds is known as wind energy. For this, windmills have been used for hundreds of years to pump out water from the ground. We use large tall wind turbines that allow winds to generate electricity. The natural airflow on the surface of the Earth is used to run the wind turbines.

The modern-day wind turbines range from about 600 Kilowatt to 5 Megawatt, for commercial purposes; these are rated with an output power of 1.5 to 3 Megawatt. The most preferred locations for these wind turbines to be installed are the areas which are strong and have constant airflows on offshore and sites that are at high altitudes.

Development of wind power in India began in December 1952, when Maneklal S Thacker, a distinguished power engineer, initiated a project with the Indian CSIR(Council of Scientific and Industrial Research) to find out the probability of harnessing wind power in the country. A Wind Power Sub-Committee was set up by CSIR, under P. Nilakantan, which was assigned the task of investigating the available resources that could be practically utilized, along with researching the economic possibilities of wind energy. Assistance was provided by the IMD(Indian Meteorological Department), the Sub-Committee extensively reviewed available data on surface winds in India and their velocity duration, and began detailed surveys of promising sites for harnessing the optimum amount of wind energy; it also successfully developed and tested large wood-and-bamboo windmills.

CSIR established a Wind Power Division In 1960, as part of the new National Aeronautical Laboratory (NAL) in Bangalore, which was founded that year. From the 1960s to the 1980s, the NAL and other groups continued to carry out wind velocity surveys and develop improved estimates of India's wind energy capacity. With the setting up of the first wind project in Veraval, Gujarat, in 1985, wind power development began, it was a 40-kW Dutch machine connected to the grid. Subsequently, the government launched several demonstration wind projects.

In 2015, the Government had set the target for Wind Power generation capacity by the year 2022 at 60,000 MW (60GW). The estimated potential of generating wind energy in India, at a mast height of 100 meters above the ground, is 302 GW (ACCORDING TO MINISTRY OF NEW AND RENEWABLE ENERGY). India had become the country with the fourth-largest installed capacity of wind power, behind China, USA, and Germany.

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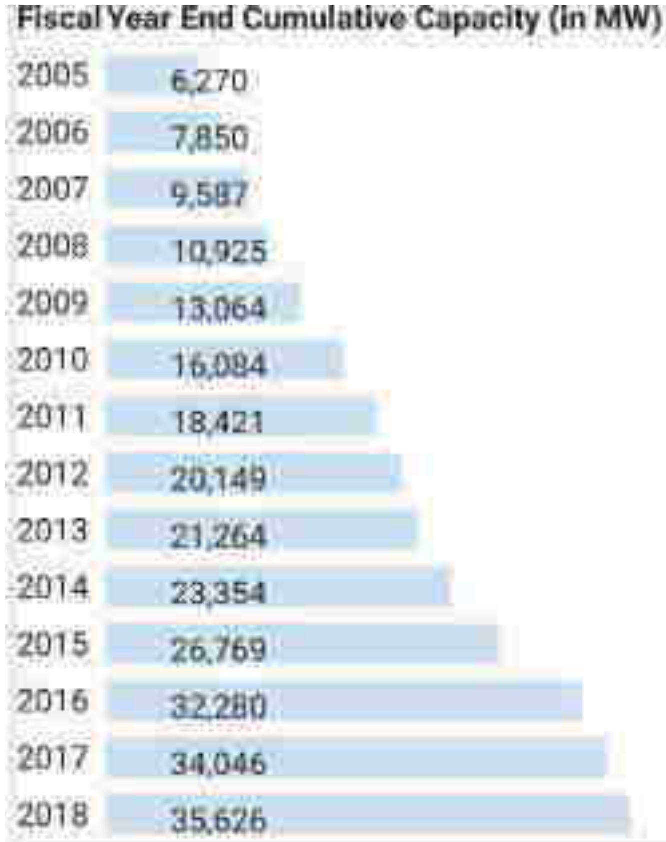


Fig 5.16: Cumulative capacity of Installed wind power

(image source:MNRE)

Several Wind power projects are established in the country, including in Rajasthan, Gujarat, Madhya Pradesh among others, on commercial lines taking into account wind resource, land availability, transmission infrastructure, etc.

So far, bids for 15,100 MW of wind power projects have been issued, out of which projects of 12,162.50 MW capacity have been awarded.

The cumulative installed capacity of wind power (as on 31.10.2019) in the country is 37,090.03 MW.[source :*Ministry of New and Renewable Energy*]

MINISTRY OF NEW AND RENEWABLE ENERGY, has issued 'Guidelines for Development of Onshore Wind Power Projects' on 22 October 2016 intending to develop wind power projects in an efficient, cost-effective and environmentally sustainable manner taking into account the requirements of project developers, States and national imperatives. The Guidelines have provisions for the requirement of site feasibility, type and quality certified wind turbines, micrositing criteria, compliance of grid regulations, real-time monitoring, online registry and performance reporting, health and safety provisions, decommissioning plan, etc.

The government has also issued 'Guidelines for Tariff Based Competitive Bidding Process for Procurement of Power from Grid Connected Wind Power Projects', on 8 December 2017, to provide a framework for procurement of wind power through a transparent process of bidding including standardization of the process and defining of roles and responsibilities of various stakeholders.

The government is promoting capacity addition of wind power projects through private sector investment by providing various fiscal and financial incentives such as Accelerated Depreciation benefit; concessional custom duty exemption on certain components of electric wind generators. Wind projects commissioned before 31 March 2017 are eligible for Generation Based Incentive (GBI). Technical support, including wind resource assessment and identification of potential sites, is being provided, In addition to fiscal and other incentives as stated above, through the National Institute of Wind Energy, Chennai.

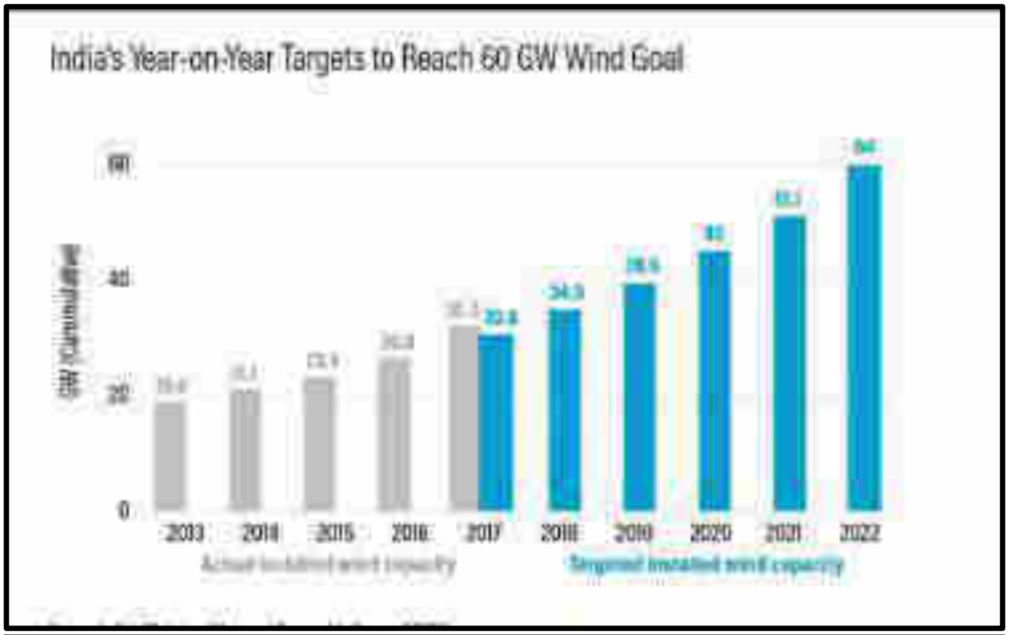


Fig 5.17: Year on Year Wind power Status in India

(Image source: World Resources Institutions)

National Institute of Wind Energy (NIWE)

Set up in the year 1998 in Chennai, It is an institution working under the Ministry of New and Renewable aims at developing wind energy and to help India achieve self-reliance in the power sector supplementing the core conventional resources. MNRE has been planning and developing the basic infrastructure, institutions, and resources for carrying out research and development, large scale demonstration and diffusion of the non-conventional energy sources.

It has a Wind turbines test station at Kayathar, which works with technical support from the Government of Denmark.

Advantages of Wind Energy:

- Onshore wind farms have a lesser cost than conventional energy generation and thus allow for mass farms of wind turbines to be set up.
- The shorter distance between the windmill and the consumer allows for less voltage drop off on the cabling.

- Wind turbines can be installed in a short period; hence unlike a nuclear power station, which can take over twenty years, a windmill can be built in a few months.
- Environmentally sustainable and provide economy of scale for the owners
- In the case of offshore wind farms, large scale windmills can be installed along with suitable conditions for installation and functioning.

Limitations of wind energy:

- Their efficiencies are limited to some 50-70% of the Betz limit.
- Wind turbine towers are at most a few hundred feet tall, winds at higher elevations from the ground are not utilized.
- It assumes almost certainly incorrect that there will be no further developments or improvements in wind turbine technology.
- The Wind Fluctuates. Wind energy has a similar drawback to solar energy in that it is not constant.
- Wind Turbines Pose a Threat to Wildlife

Recent Initiatives by the Government:

- India has a strong manufacturing base of wind power equipment in the country. There are a number of wind turbine manufacturers in INDIA. Wind turbines being manufactured in India are of international quality standards and cost-wise amongst the lowest in the world being exported to Europe, USA and other countries.
- **Online wind atlas** is available on NIWE website. This will create a new dimension to the wind power development in the country.
- **National Offshore Wind Energy Policy, notified in 2015, has an objective of developing the offshore wind energy in the Indian Exclusive Economic Zone (EEZ) along the Indian coastline.**

- **National Wind-Solar Hybrid Policy:-**
    - The main objective of the Policy is to provide a framework for the promotion of large grid connected wind-solar PV hybrid systems for optimal and efficient utilization of wind and solar resources, transmission infrastructure and land.

    - The wind-solar PV hybrid systems will help in reducing the variability in renewable power generation and achieving better grid stability. The policy also aims to encourage new technologies, methods and way-outs involving combined operation of wind and solar PV plants.
- Potential renewable energy zones (66.5 GW – Solar 50 GW and Wind 16.5 GW) have been identified in the states of Tamil Nadu, Andhra Pradesh, Karnataka, Gujarat, Maharashtra, Rajasthan & Madhya Pradesh and a comprehensive transmission scheme was evolved integrating these renewable energy zones.
- **Indian Wind Turbines Certification Scheme:** Ministry of New and Renewable Energy, in consultation with National Institute of Wind Energy Chennai, has prepared a draft of new Scheme called Indian Wind Turbine Certification Scheme (IWTCS) incorporating various guidelines Turbine Certification Scheme (IWTCS).The draft Scheme enlists the guidelines for the benefit of all the stakeholders from concept to lifetime of wind turbine, including Indian Type Approved Model (ITAM), Indian Type Certification Scheme (ITCS), Wind Farm Project Certification Scheme (WFPS) and Wind Turbine Safety & Performance Certification Scheme (WTSPCS).The WITCH is envisaged to assist and facilitate the following stakeholders; (i.) Original Equipment Manufacturers (OEMs) (ii.) End Users -Utilities, SNAs, Developers, IPPs, Owners, Authorities, Investors and Insurers (iii.) Certification Bodies (iv.) Testing Laboratories.
- National Institute of Wind Energy (NIWE), is an autonomous institution under the Ministryof New and Renewable Energy which has installed a remote sensing instrument-LiDAR for assessment of offshore wind resources in the Gulf of Khambhat, off the Gujarat Coast.

Over the decades,wind energy has matured enough to be the mainstream source of renewable power generation in India. The steady growth of the sector has seen different types of wind turbines with diverse performance and safety criteria. The Ministry of New and Renewable Energy (MNRE), Government of India through various policies and schemes has facilitated the healthy and orderly growth of the wind energy sector.

HYDROPOWER IN INDIA

Hydroelectricity is the conversion of mechanical energy in flowing water into electricity. Hydroelectricity is generated when the force of falling water from dams, rivers or waterfalls is used to turn turbines, which then drives generators that produce electricity. The energy produced is directed to a substation, where transformers "step up" the voltage before its transmission to the electricity grid.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 waterfalls 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.

The conversion of the mechanical energy in flowing water into electricity is called hydroelectricity. When a force of falling water from dams, rivers or waterfalls is used to turn turbines, it drives generators that produce electricity, and this is the process of its generation. The energy produced is directed to a substation, where transformers "step up" the voltage before its transmission to the electricity grid.

The first step involved in the generation of energy in a hydroelectric power 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 waterfalls 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.

Fig :5.18 Small Hydro Projects

(imagesource: Science direct.com)

Classification of Hydro Projects based on Installed Capacity:

Hydropower projects are mainly classified into two segments, i.e. small and large hydro. In India, hydro projects that have up to 25 MW capacities are categorized as Small Hydro Power (SHP) projects.

- Micro: up to 100 KW
- Mini: 101KW to 2 MW
- Small: 2 MW to 25 MW
- Mega: Hydro projects with installed capacity >= 500 MW
- Thermal Projects with installed capacity >=1500 MW

For large hydro projects, the Ministry of Power, Government of India is responsible. In contrast, for the small hydropower projects (up to 25 MW) the Ministry of New and Renewable Energy is responsible.

India is bestowed with a large hydropower potential of 1,45,320 MW of which only about 45,400 MW has been utilized till now. Only Around 10,000 MW of hydropower has been added in the last ten years. The hydropower sector is presently under a challenging phase, and the share of hydropower in the total capacity has declined from 50.36% in the 1960s to around 13% in 2018-19. As the country has targeted to add 160 GW of intermittent Solar and Wind power by 2022 and 40% of the total capacity from non-fossil fuel sources by 2030 to honour its Nationally Determined Contribution for Climate Change, the importance of hydropower is increasing even more.

Note: India is 7th largest producer of Hydroelectric Power in the world.

River System	Potential (MW)	% to total potential
East flowing rivers of South India	8,626	21.0
West flowing rivers of South India	4,346	10.6
Rivers of CentralIndia	4,287	10.4
GangaBasin (minus Nepal)	4,828	11.7
BrahmaputraBasin	12,486	30.3
IndusBasin	6,583	16.0
India (Total)	41,156	100.0

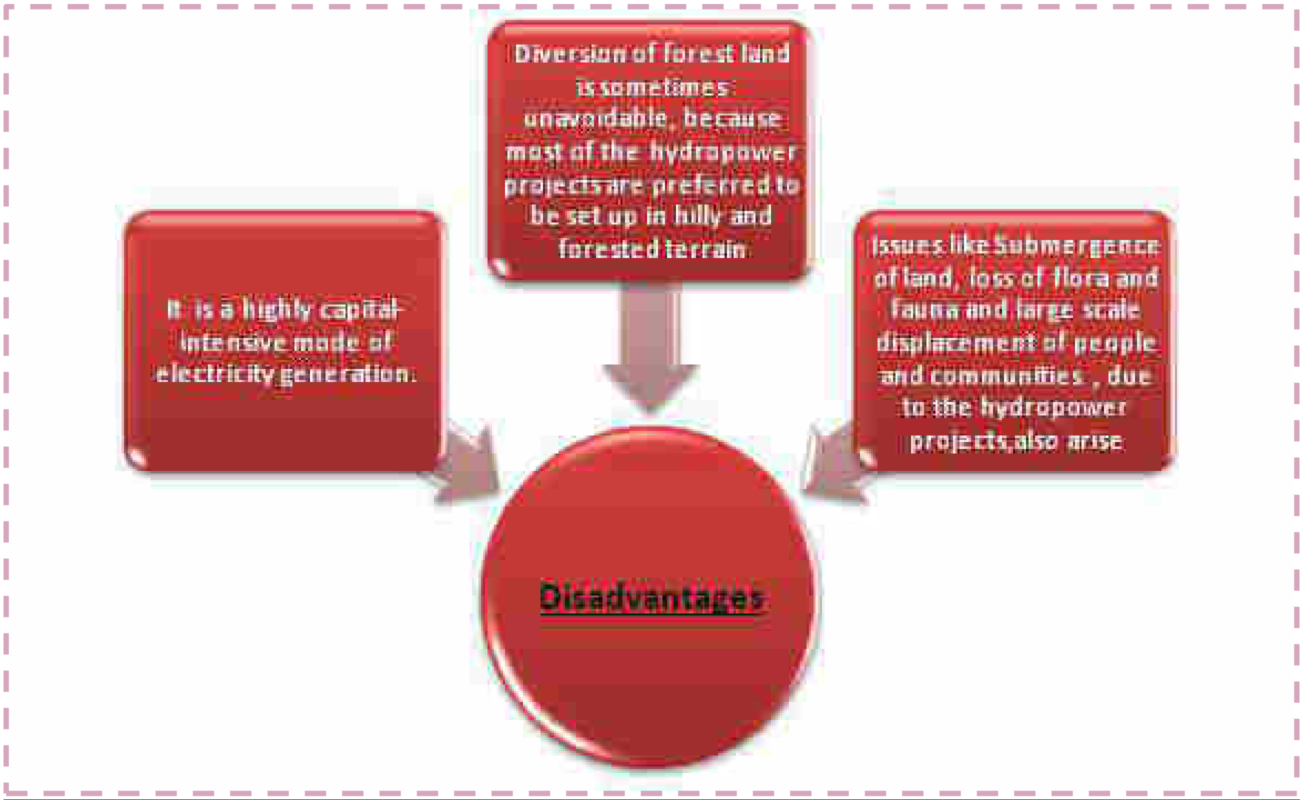
Fig 5.19 Potential of Hydropower

(image source: researchgate)

Advantages of Hydropower:

As Hydropower only utilises and not consumes water,it is a renewable source of energy because for generation of electricity, and the hydropower leaves this vital resource available for other uses.	These stations are a preferred solution for meeting peak loads in grids because they have unique capabilities of quick starting and closing.
It is a renewable source of energy with no consumables involved; hence it has a little recurring cost and no high long term expenditure. As compared to electricity generated from coal and gas-fired plants, this energy is cheaper. It decreases the financial losses due to frequency fluctuations.	The operational needs of hydro & thermal stations are complimentary, and the balanced mix helps in optimal utilization of the capacity. Seasonal load curves of regional grids match with the pattern of hydropower generation. During the summer/monsoon season, when the generation at hydropower plants is high, the load factor of the system is high due to heavy agricultural load. During winter, the thermal stations operating at base load and hydro stations working as peak load stations will take care of weather beating loads.

Disadvantages of Hydropower



Initiatives for Hydropower Development:

- As per approval of the Cabinet,Large Hydropower Projects will now be declared as Renewable Energy source (as per existing practice, only hydropower projects less than 25MW are categorized as Renewable Energy).
- The Government has declared Hydropower Projects as a separate entity within non-solar Renewable Purchase Obligation in order to cover large hydro projects commissioned after notification of these measures (SHPs are already covered under Non-Solar Renewable Purchase Obligation).
- To expedite development of hydropower projects, a Hydropower policy has been formulated. Many States have followed the kinetic and adopted the hydropower policy
- The Centre and many states have initiated hydro projects in PPP mode to attract investors for the development of water resources in an environment-friendly manner and to generate revenue while ensuring project viability.

GEOTHERMAL ENERGY:

Geothermal energy is the thermal energy generated and stored inside the Earth's crust. The centre of the Earth remains at the same temperature as the Sun, which is nearly constant due to the continuous process of nuclear fusion. Due to such high temperature and pressure, some rocks melt, which results in the upward motion of the mantle (as they become lighter with the heat). These molten rocks formed in the Earth's crust are pushed upward where they get trapped in certain regions called 'hot spots'.If underground water comes in touch or proximity with the hot spot, steam is generated. Sometimes this hot water formed region finds outlets at the surface. When this hot water gushes out of one of these outlets, it is called hot springs. To harness the geothermal energy, a hydrothermal convection system is used. In this process, a hole is drilled deep under the Earth, through which a pipe is inserted. The steam trapped in the rocks is routed through this pipe to the surface of the Earth. This steam is then used to turn the blades of a turbine of an electric generator. In another method, the steam is used to heat water from an external source which is then used to rotate the turbine.

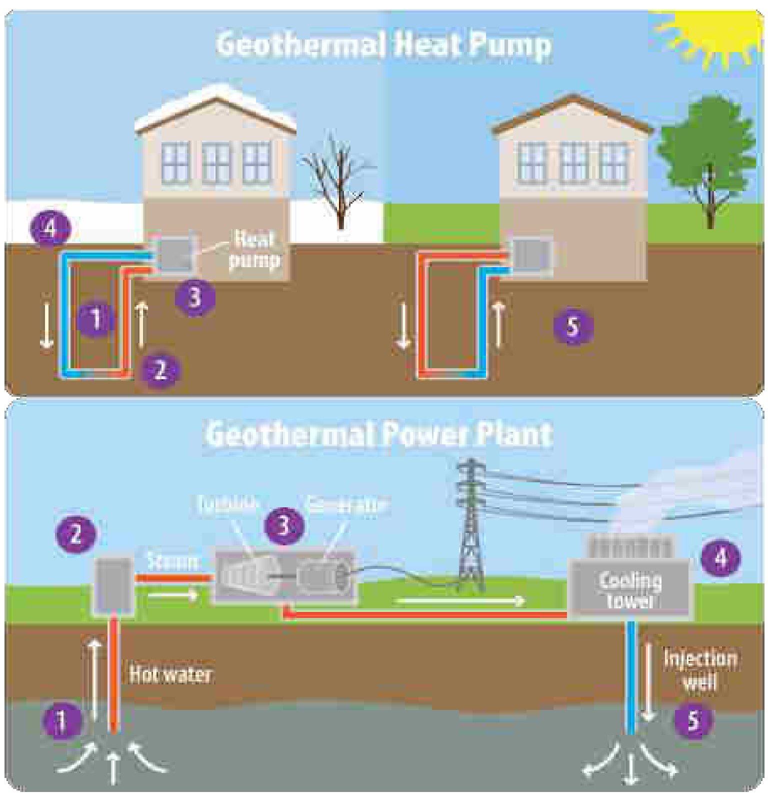


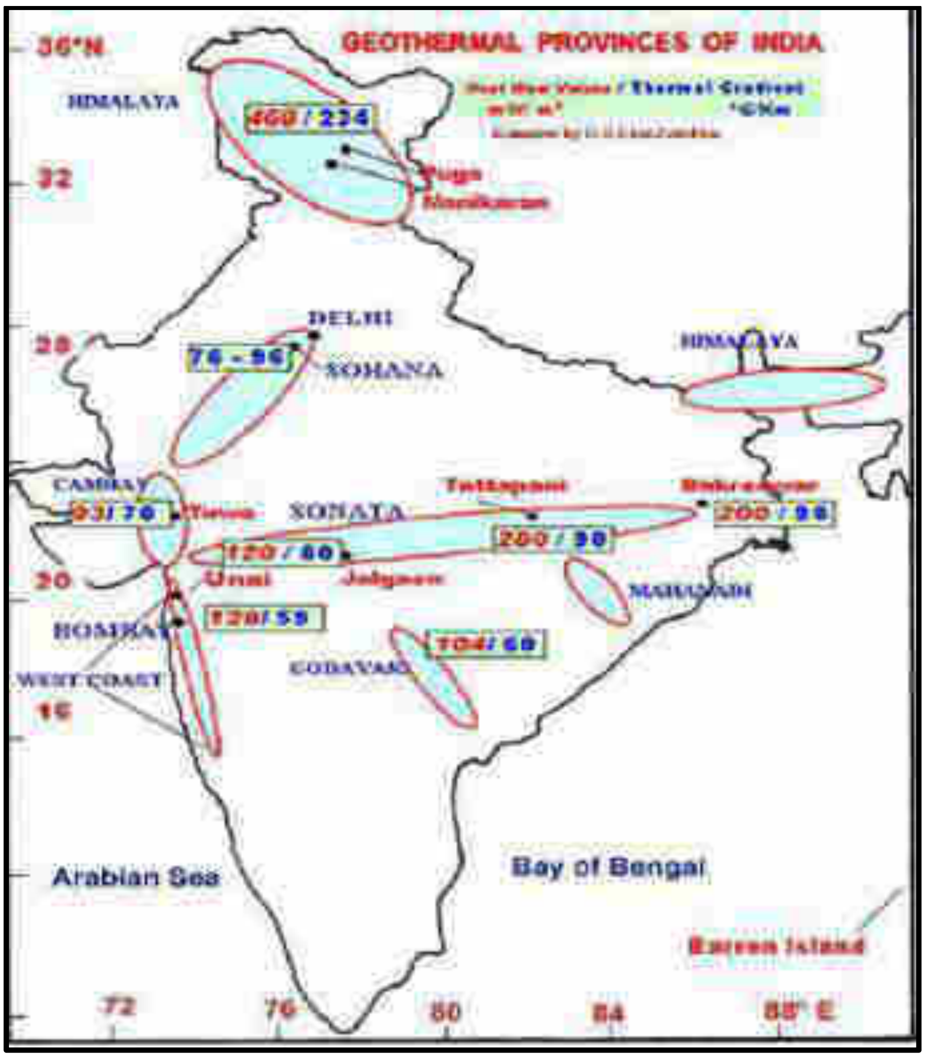
Fig 5.20 Geothermal Energy

(*Image source: byjus.com)*

In India, exploration and study of geothermal fields started in 1970. The GSI (Geological Survey of India) has identified 350 geothermal energy locations in the country. The most promising of these is in Puga valley of Ladakh. The estimated potential for geothermal energy in India is about 10000 MW.

There are seven geothermal provinces in India

- Himalayas, Sohana, West coast, Cambay, Son-Narmada-Tapi (SONATA), Godavari, and Mahanadi.



<u>Fig 5.21: Geothermal Provinces in India</u>

(image source:India energy portal)

In its quest to increase its renewable energy portfolio, India proposes to harness 10,000 MW (10 GW) of geothermal energy by 2030 through active international collaboration with countries such as the US, Philippines, Mexico and New Zealand. India is at a nascent stage in terms of exploitation of geothermal energy, primarily because coal is cheaper. But with increasing environmental problems associated with coal-based projects, India is now also looking at developing clean and eco-friendly energy sources.

Though India has been one of the earliest countries to begin geothermal projects way back in the 1970s, at present, there are no operational geothermal plants in India.

However, in Dholera, Gujarat 20 MW capacity Geothermal plant is being proposed to be run as soon as possible.

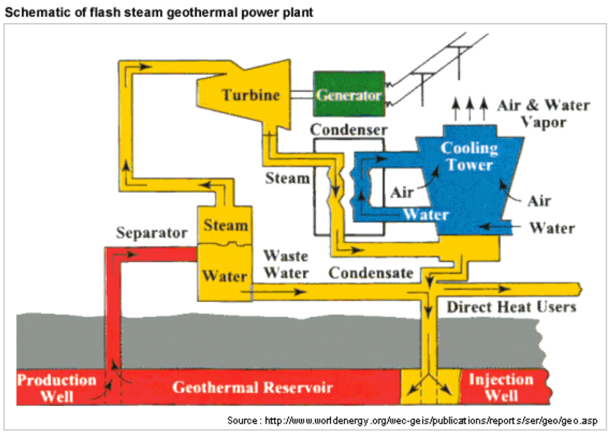
There is also no installed geothermal electricity generating capacity as of now, and only direct uses (eg.Drying) have been detailed.

Thermax, a capital goods manufacturer, based in Pune, has entered an agreement with Icelandic firm Reykjavík Geothermal.

Thermax is planning to set up a 3 MW pilot project in Puga Valley, Ladakh (Jammu & Kashmir). Reykjavík Geothermal will assist Thermax in exploration and drilling of the site.

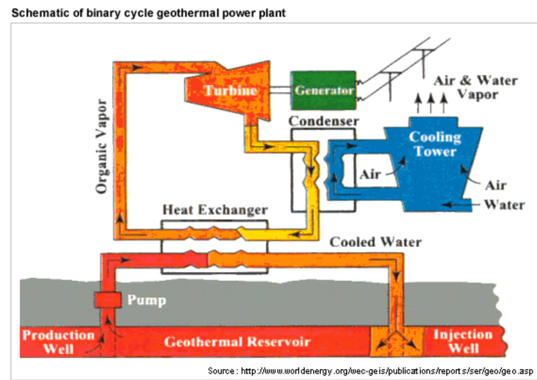
Technology for electricity generation:

Flash Steam Plants	Binary Plants
When the geothermal energy is available at 150 °C and above temperature, the fluids can be used directly to generate electricity. In some cases, direct steam is available from the geothermal reservoir; otherwise the steam is separated and turbines are used for power generation.	These plants are used when geothermal temperature is between 100 °C and 150 °C. The fluid is extracted and circulated through a heat exchanger where the heat is transferred to the low boiling point organic liquid. This gets converted into high pressure vapour, which drives organic fluid turbines.



<u>Fig 5.22 Flash Steam process</u>

(Image source: http://www.indiaenergyportal.org/subthemes_link.php?text=geothermal&themeid=13)



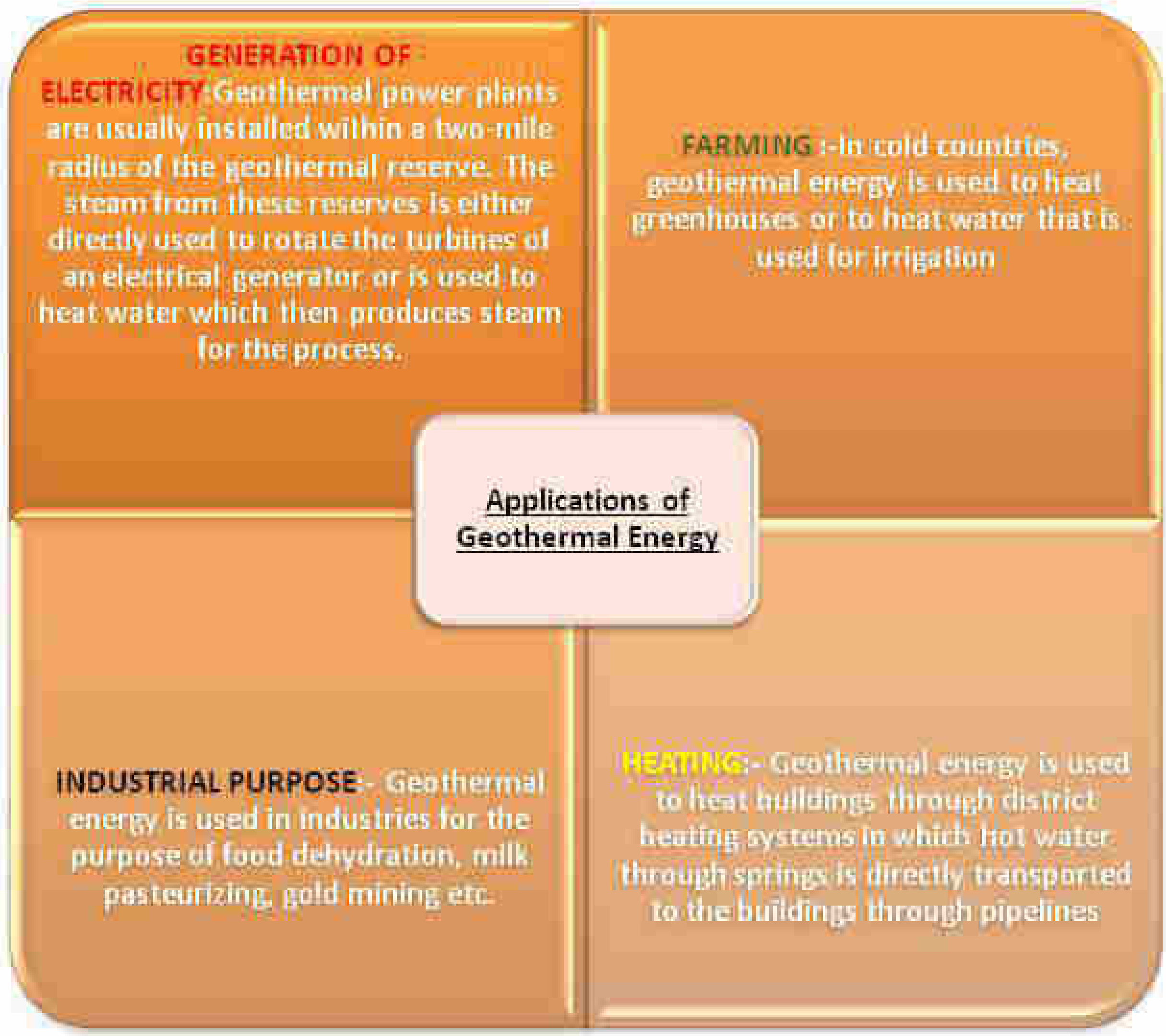
<u>Fig 5.23 Binary Use of Geothermal energy</u>

(Image source: http://www.indiaenergyportal.org/subthemes_link.php?text=geothermal&themeid=13)

<u>Indian organisations working in geothermal energy:</u>

- Central Electricity Authority
- Geological Survey of India
- Indian Institute of Technology, Mumbai
- Regional Research Laboratory, Jammu
- National Geophysical Research Institute, Hyderabad
- Oil and Natural Gas Corporation, Dehradun

Note: Several projects have been Ongoing in **India**: **Magneto-telluric investigations in Tattapani, Geothermal area in Madhya Pradesh, Magneto-telluric investigations in Puga, Geothermal area in Ladakh region, Jammu & Kashmir.**


GENERATION OF ELECTRICITY:Geothermal power plants are usually installed within a two-mile radius of the geothermal reserve. The steam from these reserves is either directly used to rotate the turbines of an electrical generator or is used to heat water which then produces steam for the process.
FARMING :-In cold countries, geothermal energy is used to heat greenhouses or to heat water that is used for irrigation
Applications of Geothermal Energy
INDUSTRIAL PURPOSE:- Geothermal energy is used in industries for the purpose of food dehydration, milk pasteurizing, gold mining etc.
HEATING:- Geothermal energy is used to heat buildings through district heating systems in which hot water through springs is directly transported to the buildings through pipelines

Advantages Of Geothermal Energy	• Renewable resource: Geothermal energy is free and abundant. The constant flow of heat from the Earth makes this resource inexhaustible and limitless to an estimated time span of 4 billion years. • Green energy: Geothermal energy is non-polluting and environment-friendly as no harmful gases are evolved with the use of geothermal energy unlike the use of fossil fuels. Also, no residue or by-product is generated. • Generation of employment: Geothermal power plants are highly sophisticated and involve large scale research before installation. This generates employment for skilled and unskilled labours at a very large scale at each stage of production and management. • Can be used directly: In cold countries, the geothermal energy is used directly for melting of ice on the roads, heating houses in winters, greenhouses, public baths etc. Although the initial cost of installation is very high, the cost for maintenance and repair is negligible.
Disadvantages of Geothermal Energy	• Transportation and transmission: Unlike fossil fuels, geothermal energy cannot be transported easily. Once the tapped energy is harnessed it can only be used efficiently in the nearby areas. Also, with the transmission, there are chances of emission of toxic gases getting released into the atmosphere. • High installation cost: The installation of geothermal power plants to get steam from deep under the Earth requires a huge investment in terms of material and human resource. • Intensive research required: Before setting up a plant, extensive research is required, as the sites can run out of steam over a period of time due to a drop in the temperature as a result of excessive or irregular supply of inlet water. • Limited to particular regions: The source of geothermal energy is available in limited regions, some of which are highly inaccessible such as high rise mountains and rocky terrains, which renders the process economically infeasible in many of the cases. • Impact to the environment: Geothermal sites are

	present deep under the earth, so the process of drilling may result in the release of highly toxic gases into the environment near these sites, which sometimes prove fatal to the workforce involved in the process.

<u>Recent Initiatives By Government to Promote Geothermal Energy:</u>

- Geothermal Atlas of India, prepared by the Geological Survey of India(GSI) gives information/data for more than 300 geothermal potential sites. This Atlas is being updated by GSI with the support from MNES.
- Applications of geothermal energy for small-scale power generation and thermal applications are being explored.
- Gujarat has become the first state and is planning to implement its geothermal energy policy
- India proposes to harness 1,000 MW of geothermal energy till 2022 and 10,000 MW by 2030.
- **Draft Geothermal Energy Policy:**
    - The geothermal policy envisages to make a substantial contribution to India's long-term energy supply and reduce our national greenhouse gas emissions by developing a sustainable, safe, secure, socially and environmentally responsible geothermal energy industry.
    - It seeks to create new employment opportunities in Geothermal Sector
    - Promotion of environmentally sound sustainable development by the means of deployment of 1,000 MW(therm) and 20 MW(elect) Geothermal Energy Capacity in the initial phase till 2022 and 10,000 MW(therm) & 100 MW(elect) by 2030.
    - The policy seeks to mitigate electricity demand by deploying Ground Source Heat Pumps (GSHP'S) and retrofitting the existing HVAC systems with Geo-exchange based systems.
- Ministry of New and Renewable Energy is planning to encourage the International Collaboration with the world leaders in Geothermal Energy like USA, Philippines, Indonesia, Mexico and New Zealand for support to accelerate deployment of geothermal

energy by international investment promotion (100% FDI in RE Sector), Customized capacity building and technical assistance to key stakeholders, help in mitigating the exploratory risk, technological support etc.

OCEAN THERMAL ENERGY:

Oceans are a source of two major types of **Renewable energy source**

- **Thermal energy** - Which is produced by the heat of the Sun
- **Mechanical energy** - Which is produced from wave action and tides namely,
    - Tidal Energy
    - Wave Energy Ocean Thermal Energy is also called as Ocean Thermal Energy Conversion (OTEC) is a **method of using the temperature difference between the deep parts of the sea which are cold and the shallow parts of the sea which are cold to run a heat engine and produce useful work.**

Ocean thermal energy conversion is an electricity generation system. The deeper parts of the ocean are cooler since the heat of sunlight cannot penetrate very deep into the water. Here the efficiency of the system depends on the temperature difference: greater the temperature difference, greater the efficiency.

The temperature difference in the oceans between the deep and shallow parts is maximum in the tropics, 20 to 25-degree C. Tropics receive a lot of sunlight which warms the surface of the oceans, increasing the temperature gradient.

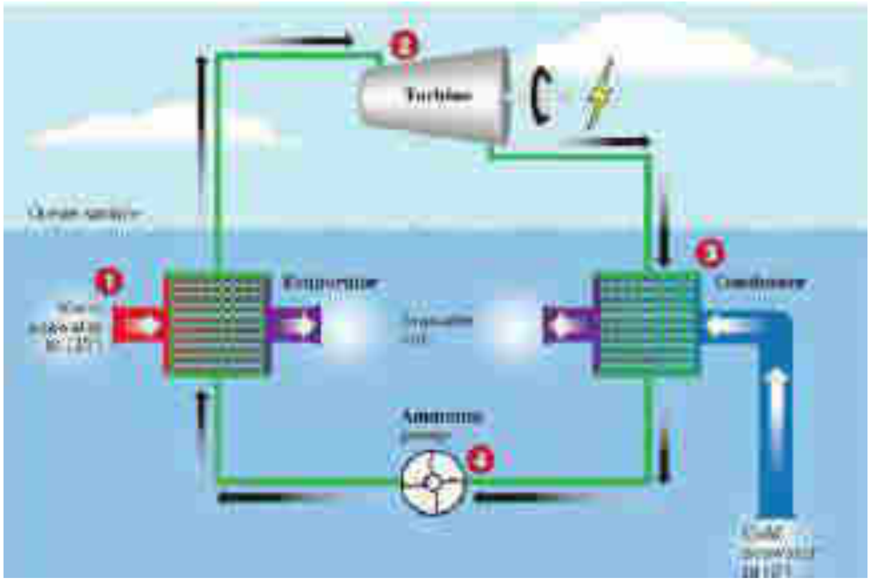


Fig 5.24-OTEC -process

(Image source: byjus.com)

The energy source of OTEC is abundantly available, free and will be so for as long as the sun shines and ocean currents exist. Estimates suggest that ocean thermal energy could contain more than twice the world's electricity demand. This makes it necessary for us to give it a closer look.

Types of Ocean Thermal Energy Conversion (OTEC):

	Types of Ocean Thermal Energy Conversion (OTEC):
Closed Cycle	Closed cycle Ocean Thermal Energy Conversion systems use a working fluid with a low boiling point, Ammonia for example, and use it to power a turbine to generate electricity. Warm seawater is taken in from the surface of the oceans and cold water from the deep. The warm seawater evaporates the fluid in the heat exchanger which then turns the turbines of the generator. The fluid now in the vapour state is brought in contact with cold water which turns it back into a liquid. The fluid is recycled in the system which is why it is called a closed system.

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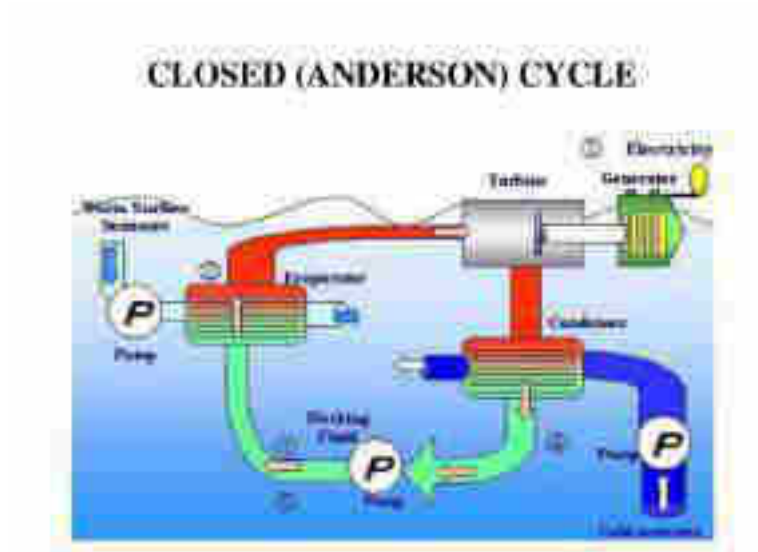
<td>
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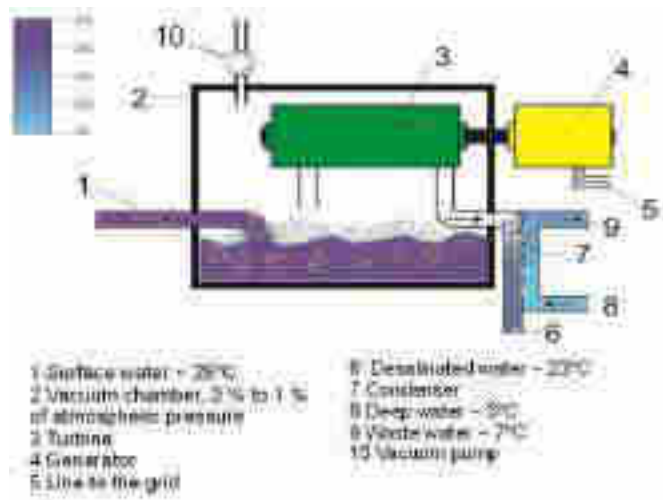
<td>Open Cycle</td>
<td>Open cycle OTEC directly uses the warm water from the surface to make electricity. The warm seawater is first pumped in a low-pressure chamber where due to the drop in pressure, it undergoes a drop in boiling point as well. This causes the water to boil. This steam drives a low-pressure turbine which is attached to an electrical generator. The advantage this system has over a closed system is that, in open cycle, desalinated water in the form of steam is obtained. Since it is steam, it is free from all impurities. This water can be used for domestic, industrial or agricultural purposes.

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Ocean Thermal Energy (OTEC) is a real candidate as one of the future sources of energy. Its environmental impact is negligible, in fact, the mixing of deep and shallow seawater brings up nutrients from the seafloor. The deepwater is rich in nitrates and this can also be used in agriculture.

Types of Ocean Thermal Energy Conversion:

THERMAL ENERGY

Thermal energy is the energy that comes from the temperature of matter. The hotter the substance, the more is the vibration of molecules and hence the higher is the thermal energy.

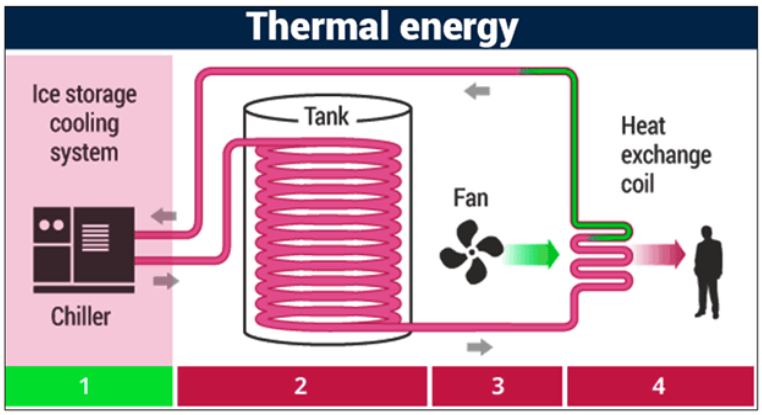


Fig 5.25 Thermal Energy Mechanism

(image source:byjus)

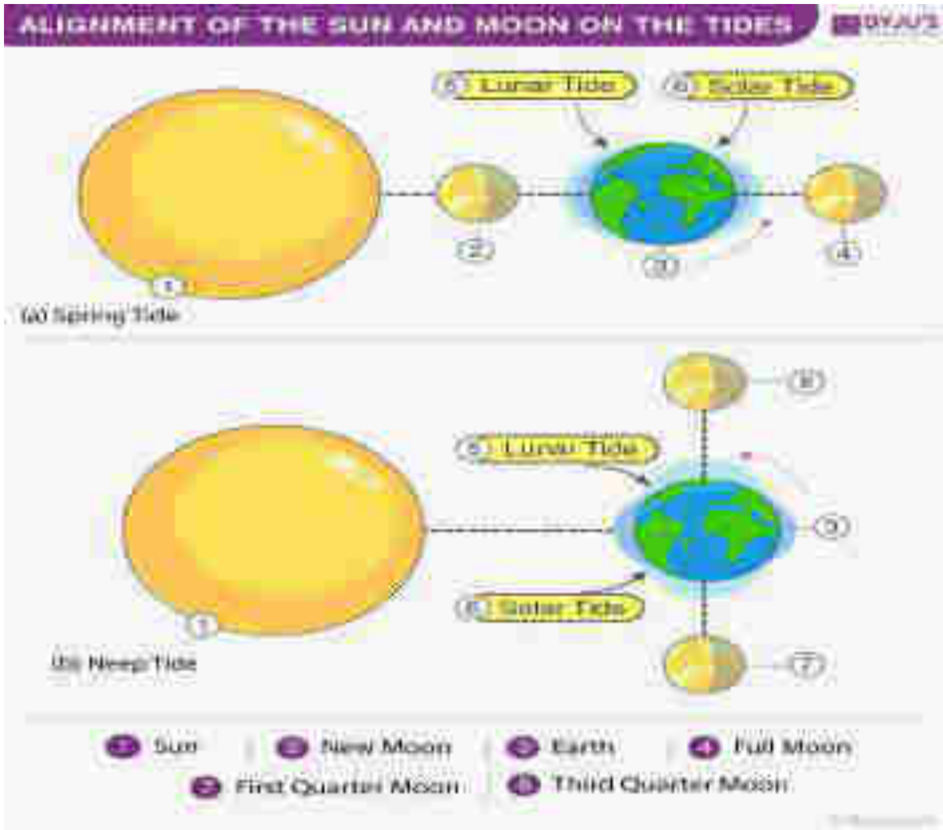
The water at the surface of the sea or ocean is heated by the Sun while the water in deeper sections is relatively cold. This difference in temperature is exploited to obtain energy in ocean-thermal-energy conversion plants. These plants can operate if the temperature difference between the water at the surface and water at depths up to 2 km is 20 K (20°C) or more. The warm surface-water is used to boil a volatile liquid like ammonia. The vapours of the liquid are then used to run the turbine of the generator. The cold water from the depth of the ocean is pumped up and condenses vapour again to liquid.

TIDAL ENERGY:

Tides are a regular phenomenon. They can be predicted over months and years in advance. This is why the energy from this massive movement of water can be harnessed and converted into a usable form of energy.

The gravitational forces of the sun and the moon combined with the rotation of the earth result in an alternate rise and fall of the sea levels. At one particular place, it usually occurs twice on a lunar day. The rise of the sea level is called the high tide, whereas the fall is called the low tide. When the earth and moon's gravitational fields are in a straight line, the influences of these two fields become very strong and cause millions of gallons of water flow towards the shore resulting in the high tide condition. Likewise, when the moon and earth's gravitational fields are perpendicular to each other, the influences of these fields become weak causing the water to flow away from the shore resulting in a low tide condition.

When the moon is perfectly aligned with the earth and the sun, the gravitational pull of the sun and the moon on the earth becomes much stronger and the high tides much higher and the low tides much lower during each tidal cycle. This condition occurs during the full or new moon phase. Such tides are known as spring tides. Similarly, another tidal situation emerges when the gravitational pull of the moon and sun are against each other cancelling their effects. This results in a smaller difference between the low and high tides due to the smaller pulling action on the sea water, thereby resulting in weak tides. These weak tides are known as neap tides. Neap tides occur during the quarter moon phase.



<u>Fig 5.26 Mechanism for Tides</u>

(Image source: byjus.com)

The energy obtained from the rise and fall of tides is called the tidal energy.

Tidal barrages or dams are constructed across a narrow opening to the sea. Water rushes into the dam when the sea level rises. This moves the blades of the turbines which are attached at the opening of the dam. This results in the generation of electricity.

<u>ENERGY FROM WAVE AND CURRENTS:</u>

You may have noticed that there is a certain kind of air force when you go near any seashore. This is due to a type of energy which gets transported by wind waves. This energy is also known as wave power. When the wind passes on the water surface, it leads to the pressure difference between the upper and bottom wind which results in the generation of waves. This wave energy which is captured can be used for several useful works namely water distillation, electric generator, and WEC. The motion of waves contains a different degree of energy. The <u>electromagnetic waves</u> from the wave energy give us energy for sustaining life on earth. Water desalination or the pumping of water into reservoirs are some of the uses of the wave power, electricity generation, etc. Some of the main properties of waves include speed, frequency, period, amplitude and wavelength. Ocean wave energy is a natural source of energy which is directly captured from the pressure fluctuations below the surface or from the surface area itself. They are therefore of two types namely:

- **Ocean Thermal Energy**
- **Ocean Mechanical Energy**

In Ocean Mechanical Energy, electricity is produced by taking energy from the ocean in three main types:

1. The channel systems, which are used to funnel the waves into reservoirs.
2. Float systems are used to run the hydraulic pumps.
3. The column system is used to compress the air present within the containers.

Ocean wave power is then used to rotate the turbine or the generator and the electricity is produced. Ocean Thermal Energy uses the temperature of the surface sea waters to run a heat engine and produce electricity. Ocean water moving in one direction is called marine current. This ocean current is known as the Gulf Stream. Currents are also by tides. Kinetic energy can be captured from the Gulf Stream and other tidal currents with submerged turbines that are very similar in appearance to miniature wind turbines. Similar to wind turbines, the movement of the marine current moves the rotor blades to generate electric power.

Developments in the field of Ocean Thermal Energy Systems:

In order to increase its efforts to reach the objectives of Renewable Energy generation and climate change objectives post-2022, it is a necessity to explore all possible avenues to stimulate innovation, create economic growth and new jobs as well as to reduce our carbon footprint. India has a long coastline with the estuaries and gulfs. The Ministry of New and Renewable Energy (MNRE) looks over the horizon at the development of new technology and considers the various options available to support its deployment. Most types of technologies are currently at pre-R&D / demonstration stage or the initial stage of commercialization. Basic R&D is being looked after by the Ministry of Earth Sciences (example: National Institute of Ocean Technology, Chennai). MNRE intends to support demonstration projects of proven technologies and as approved by an expert committee constituted by MNRE.

- The estimated potential of Tidal Energy is about 12455 MW, with potential locations identified at Khambhat & Kutch regions, and large backwaters, where barrage technology could be used.
- The total potential of wave energy in India along the coast is around 40,000 MW – while these are preliminary estimates, this energy is, however, less intensive as compared to that which is available in more northern and southern latitudes.
- Ocean thermal energy conversion has a theoretical potential of 180,000 MW in India, but it is highly dependent on technological evolution.

In case of Tidal Energy Total identified potential is about 12455 MW, with potential locations identified at Gulf of Khambhat & Kutch regions, and large backwaters, where barrage technology could be used.

BIOMASS ENERGY:

Fig 5.27 Biomass

(Image source: Byjus.com)

The fuel developed from natural and organic materials or wastes, which are a renewable and sustainable source of energy is known as Biomass.

Few types of fuels used to generate biomass are:

a) Scrap Lumber

b) **Woody construction and Forest debris** (Wood waste, sawmill waste, green waste from landfills and other vegetative)

c) **Certain agricultural crops and wastes**

d) **Manure**

e) Animal waste

f) Ethanol waste

g) Municipal solid waste (sewage sludge or other landfill organics)

h) Landfill gas

i) Other industrial waste (i.e. paper sludge from paper recycling processes)

For generating biomass, often the energy sources are thought to be limited to plant wastes but that's not the case. Even animal-derived materials are used for biomass generation. Biomass is the prime building block of biofuels, highly used for electricity production to produce heat in the context of energy, as an alternative to fossil fuels.

The chemical composition of Biomass comprises – Carbon, Hydrogen, and Oxygen along with nitrogen and alkali atoms, heavy metals and alkaline earth.

Difference between Biomass and Other Fossil Fuels:

The first, foremost and major difference is the 'Time Difference', i.e. the time required for it to be generated. Biomass takes carbon out of the atmosphere while it is developing, and returns as it is burned. Biomass can be converted into ethanol by a thermal process and into methanol by fermentation and digestion. Fuels have a high energy density, and burning and utilizing them releases carbon dioxide into the atmosphere.

Disadvantages of Biomass:

If crops are no longer grown then there wouldn't be any agricultural wastes found. If there's a demand for biomass then harvesting methods need to be developed. Another major disadvantage is that the land used for growing crops for biomass, is occupied for the long term and which may be in need for other purposes like housing, conservation, farming, resort or agricultural use.

BIOFUEL

A biofuel is a fuel that is produced through contemporary processes from biomass, rather than a fuel produced by the very slow geological processes involved in the formation of fossil fuels, such as oil. Since biomass technically can be used as a fuel directly (e.g. wood logs), some people use the terms biomass and biofuel interchangeably.

Biofuels are of 3 types: a) Ethanol b) Biodiesel c) Biojet fuel

- **Ethanol:** is used in engines that burn gasoline most cars.
- **Biodiesel** is used in engines that burn diesel fuel like large trucks and tractors.
- **Biojet** fuel is used in planes.
- Theoretically, biofuel can be produced through any carbon source, with plants being the most commonly used material. But, ethanol is produced in a different way from Biodiesel.
- What they have in common is the need to grow the plant that will eventually be used to make the fuel. For ethanol, corn or sugarcane is first harvested and then bacteria are allowed to digest it.
- This is done under special conditions where oxygen levels are low. This process is called fermentation that produces ethanol. For Biodiesel, the process requires chemical reactions- the most common is called trans-esterification, which is the process of breaking down fats catalysed by methanol.
- Biofuel can be made from various sources like feedstock. Ethanol can be made from
    - a) Corn b) Sugarcane c) Sugar beet d) Wheat e) Grass f) Inedible parts of most plants
    - Biodiesel can be made from a cactus-like plant called Jatropha, flowering plants like Camelina, Soybeans, Rapeseed, Canola Oil, Palm Oil, Peanut Oil, Vegetable Oil, Animal Fat, and Algae Oil (Algae Oil is made by Algae that lives in water).

Today, Biomass is used to produce Biofuels that are used together with biofuels or even replace them.About 25 billion gallons of ethanol are made each year as fuel, and each year, about 1 billion gallons of biodiesel are produced.
Biofuel is a source of renewable energy, unlike fossil fuels like petrol, coal and natural gas. Further, it is cost-effective and also environmentally friendly. This makes it well suited in an age where the cost of petroleum products are rising and there is a growing concern of fossil fuels in global warming. Biofuels are subdivided into generations.

Biofuel is grouped by categories and further classified into different types.

Categories of Biofuels:

FIRST GENERATION BIOFUELS	SECOND GENERATION BIOFUELS	THIRD GENERATION BIOFUELS	FOURTH GENERATION BIOFUELS
These are the conventional biofuels that are produced directly from food crops. They are derived from starch, sugar, animal, fats, and vegetable oil. Corn, wheat and sugarcane are the most common first-generation biofuel feedstock.	The 2nd Generation Biofuels are more advanced Biofuels. They are made from various types of non-food biomass, which are plant materials and animal waste	They entered the mainstream recently, and they refer to biofuel that is derived from Algae	The 4th Generation biofuels don't require the destruction of biomass. This includes electrofuels and photobiological solar fuels. Some of these fuels are carbon-neutral.

Different types of fuels can be produced using 1st, 2nd, 3rd and 4th generation biofuels production procedures.

Biodiesel:

- Biodiesel is a renewable resource made from vegetable oil, recycled cooking oil, soybean, palm oil, peanut oil, canola oil, animal fat and fatty acids.

Bio-ethanol:

- Bio-ethanol is made from the fermentation of plant starch.
- This is also a by-product of the chemical reaction with ethylene and other types of petroleum products.

- One of the latest techniques to produce ethanol is eugenol which is done with the help of algae. Bio-ethanol is a clean gas with no toxins. It reduces greenhouse gas emissions as well (GHG's).

Biogas:

- Biogas is a renewable source of energy that is produced by the anaerobic digestion of biomass.
- It is obtained when organic matter is broken down in the absence of oxygen.
- The raw materials used are manure, food waste, municipal waste, agricultural waste and sewage used as raw materials.
- A major portion of biogas is methane and CO2. It also has small proportions of hydrogen sulfide, hydrogen carbon-monoxide.
- It is used for heating, electricity and automobiles.

Butanol:

- Butanol is similar to ethanol. It is a type of alcohol that can be produced from the petrochemical process or by the fermentation of sugar from crops.
- Its energy content is the highest when compared to other gasoline alternatives.
- It has zero toxic emissions that minimize air pollution.
- Butanol is added to diesel to reduce emissions.

It serves as a solvent in textile industries and is used as a base in perfumes.

Bio-hydrogen:

- It is similar to biogas and is produced with the help of bacteria, algae, and archaea biologically. The common methods used in its production are photo-fermentation, dark fermentation, direct photolysis, and indirect photolysis.

This year, the government approved the National Policy on Biofuels not only to help farmers economically dispose of surplus stock but also to reduce India's oil import dependence. Rajasthan became the first state to implement it.

With the first Indian airplane being flown with biofuel, there has been little doubt that biofuel can be used to run vehicles as well.

But, the truth is that biofuel can replace all human energy needs from home-heating to vehicle fuel to electricity generation. The basic concept of biofuel is that if we use as much product as is grown, then our net impact on the environment is negligible if not zero.

Uses of Biofuel and their impact on the environment:

Biofuels are as old as cars. At the beginning of the 20th Century, when Henry Ford built his first automobile, he also had plans to fuel it with ethanol. Considering that this happened over a century ago and that ethanol is still not a popular fuel, the plan did not take off.

The discovery of huge petroleum deposits kept petrol cheap for decades, and by then biofuels were largely forgotten. But a recent rise in the price of Oil and the rise and the concern about Global warming has reignited the interest in Biofuels. Estimates suggest that we have nearly hit peak-oil and that it is only a matter of time when we will run out of it. So, the need to find an alternative is clear. It is strategically very important for India that she develops her indigenous capabilities in fuels to cater to different needs. Thus, when we move towards biofuels, it is natural that we would be developing our farming industries, our rural areas, our energy security, etc. Petroleum products are in any case subject to a lot of ups and downs in the international market. Thus if we produce biofuels internally in India, then this would be a very good addition.

Many of the alternatives like wind and solar energy are non-practical as transporting them is very difficult. Thus, the solution seems to be algal-based biofuels. Algae has lipid and lipids can be converted into several fuels, including diesel, ethanol, butanol and methanol.

With this renewed interest, it is important to examine the uses of biofuels, the first being transportation. Globally, transportation accounts for 25% of all energy needs and nearly 62% of all Oil consumed. Most of this energy is burnt to operate vehicles, while the rest goes towards maintenance, manufacturing, infrastructure, and raw material harvesting.

Further, more than 70% of energy consumption in transportation is used in private cars. Thus, it is being used in the least efficient means. The other use is in the area of power generation. Electricity generation is the single largest user of fuel in the world. In 2008, the world produced over 20,261 TWh of electricity and about 41% of that came from coal, 21% came from natural gas, and the rest 16% from hydropower, 13% from nuclear, and 5% from Oil. Of the fuel burnt, only 39% went into producing energy, and the rest was lost as heat.

The third major use of biofuel is generating heat. The majority of biofuel used in heating is used as solid. The renewed interest has led to a surge of innovation in the industry with research focussing on improved efficiency, reduced emissions, and enhanced convenience.

Recently, a fuel cell was developed with cooking Oil and sugar to generate electricity. This could soon become a common method to do that.

Consumers may be able to use fuel cells in place of batteries to charge anything from computers to mobiles. Biofuels can help to clean up oil spills and grease as well. It has been tested as a potential cleaning agent in areas where Oil has contaminated waters. Biofuel can also be used for cooking; the other uses are as a motor lubricant, and to remove paint and adhesives.

The biggest advantage of biofuels is that it is biodegradable. However, developing biofuels require huge investments for water and fertilizer. In other words, more energy is put into the system than taken out; thus, it leads to a net loss. Until the input of energy is lower than what the system produces, the system cannot be viable.

NATIONAL POLICY ON BIOFUELS

- Biofuels are classified as "Basic Biofuels" viz. First Generation (1G) ethanol & biodiesel and "Advanced Biofuels" - Second Generation (2G) ethanol, Municipal Solid Waste (MSW) to drop-in fuels, Third Generation (3G) biofuels, bio-CNG etc. in order to provide adequate financial and fiscal incentives to each category.
- Under the NATIONAL POLICY, the scope of usage of raw material for ethanol production has been expanded, by allowing the use of Sugarcane Juice, Sugar containing materials like Sugar Beet, Sweet Sorghum, Starch containing materials like Corn, Cassava, Damaged food grains like wheat, broken rice, Rotten Potatoes
- Farmers are at risk of not getting appropriate prices for their produce during the surplus production phase. Taking this into account, the policy allows the use of surplus food grains for production of ethanol for blending with petrol with the approval of the National Biofuel Coordination Committee.
- The National Policy Advocates a viability gap funding scheme for 2G ethanol Bio refineries of Rs.5000 crore in 6 years, for advanced Biofuels, as well as additional tax incentives, higher purchase price as compared to 1G biofuels.
- It encourages establishing supply chain mechanisms for biodiesel production from non-edible oilseeds, Used Cooking Oil, short gestation crops.
- In order to synergize efforts roles and responsibilities of all the concerned Ministries/Departments with respect to biofuels has been captured.

Expected Benefits of the Policy:

Reduce Import Dependency: One crore lit of E10 saves Rs.28 crore of forex at current rates. The ethanol supply year 2017-18 is likely to see a supply of around 150 crore litres of ethanol which will result in savings of over Rs.4000 crore of forex.

Cleaner Environment: One crore lit of E-10 saves around 20,000 ton of CO2 emissions. For the ethanol supply year 2017-18, there will be lesser emissions of CO2 to the tune of 30 lakh ton. By reducing crop burning & conversion of agricultural residues/wastes to biofuels, there will be a further reduction in GreenHouse Gas emissions.

Health benefits: Prolonged reuse of Cooking Oil for preparing food, particularly in deep-frying, is a potential health hazard and can lead to many diseases. Used Cooking Oil is a potential feedstock for biodiesel, and its use for making biodiesel will prevent diversion of used cooking oil in the food industry.

MSW Management: It is estimated that annually 62 MMT of Municipal Solid Waste gets generated in India. There are technologies available which can convert waste/plastic, MSW to drop-in fuels. One ton of such waste has the potential to provide around 20% of the drop-in fuels.

Infrastructural Investment in Rural Areas: It is estimated that one 100klpd biorefinery will require around Rs.800 crore capital investment. At present Oil Marketing Companies are in the process of setting up twelve 2G bio refineries with an investment of around Rs.10,000 crore. Further addition of 2G biorefineries across the country will spur infrastructural investment in rural areas.

Employment Generation: One 100klpd 2G bio refinery can contribute 1200 jobs in Plant Operations, Village Level Entrepreneurs and Supply Chain Management.
Additional Income to Farmers: By adopting 2G technologies, agricultural residues/waste which otherwise are burnt by the farmers can be converted to ethanol and can fetch a price for these waste if a market is developed for the same. Also, farmers are at risk of not getting an appropriate price for their produce during the surplus production phase. Thus conversion of

surplus grains and agricultural biomass can help in price stabilization

MISCELLANEOUS

5.11 GREEN FUEL

Green fuel, also known as biofuel, is a type of fuel distilled from plants and animal materials, it is generally considered as environmentally friendly and sustainable. Green fuel has evolved as a possible fueling option and an alternative for fossils.

Generally, crops are broken down into two types: sugar producing and Oil producing, while making biofuels. These sugar and starch producing crops, like sugar cane or corn, are put through a fermentation process to create ethanol. The Oil producing plants, such as the one's used in vegetable oils, can be utilized much like fossil sources of Oil; they create diesel that can be burned by cars or further processed to become biodiesel.

Recent innovations, in the field of technology, have opened new possibilities in the fields of advanced biofuels, which focus on non-food sources and waste renewal as energy. The conversion of landfill material, as well as wood and inedible plant parts, into a form called green fuel, not only the use of fossil fuels is reduced but also effectively a large amount of waste is reduced.

A new form of fuel can be called green, as it derives from green algae. Algae, often seen growing on bodies of water, is a tiny plant with a rapid growth rate. Its utility as fuel is because it has an extremely high oil content that can be processed like other oil-producing crops. Many countries have been involved in extensive research on algae, which is easy to cultivate and grows extremely quickly. One acre of algae can produce 200 times as much oil as one acre of corn.as per estimates by start-up algae oil companies,

Some critics allege that green fuel is not free from pollution-causing attributes. The processing of sugar and starch plants into ethanol has come under heavy criticism in recent years; not only do these plants take away food-growing space, but the fermentation process also releases considerable pollution into the air. Moreover, green fuel is not necessarily clean and may emit formaldehyde, ozone, and other carcinogenic substances when used or burnt.

It is not yet clear whether the green fuel currently available is the wave of the future or merely an interim step on the journey away from fossil fuel use. Governments around the world are devoting enormous resources to the research of clean, sustainable fuels to replace the pollutant and quickly disappearing oil reserves used today. Green fuel may not be a perfect solution to the problems of oil need and global protection, but it remains an important innovation that may pave the way for a better future.

ENERGY AUDIT

Today Energy has become a key determinant of production cost at the micro-level as well as in dictating the inflation and the debt burden at the macro level. Energy cost is a significant factor in economic activity at par with factors of production like capital, land and labor.due to a situation of energy shortage and need for conservation there are requirements for energy conservation measures, which essentially mean using less energy for the same level of activity.

An Energy Audit is an inspection survey, and an analysis of energy flows for energy conservation in a building. It may include a process or system to reduce the amount of energy input into the system without negatively affecting the output. It helps in the optimization of energy costs, pollution control, safety aspects and suggests the methods to improve the operating & maintenance practices of the system. It is useful in the situation of variation in energy cost availability, reliability of supply, the decision on appropriate energy mix, decision on using improved energy conservation equipment and technology.

Objectives of Energy Audit

The Energy Audit provides the vital information base for the overall energy conservation program covering essentially energy utilization analysis and evaluation of energy conservation measures. Its objectives include:-

- Identify the quality and cost of various energy inputs.
- Relating energy inputs and production output.
- Identifying potential areas of the thermal and electrical energy economy.
- It highlights wastage in major areas.
- Fixing of energy saving potential targets for individual cost centers.
- Implementation of measures for energy conservation & realization of savings

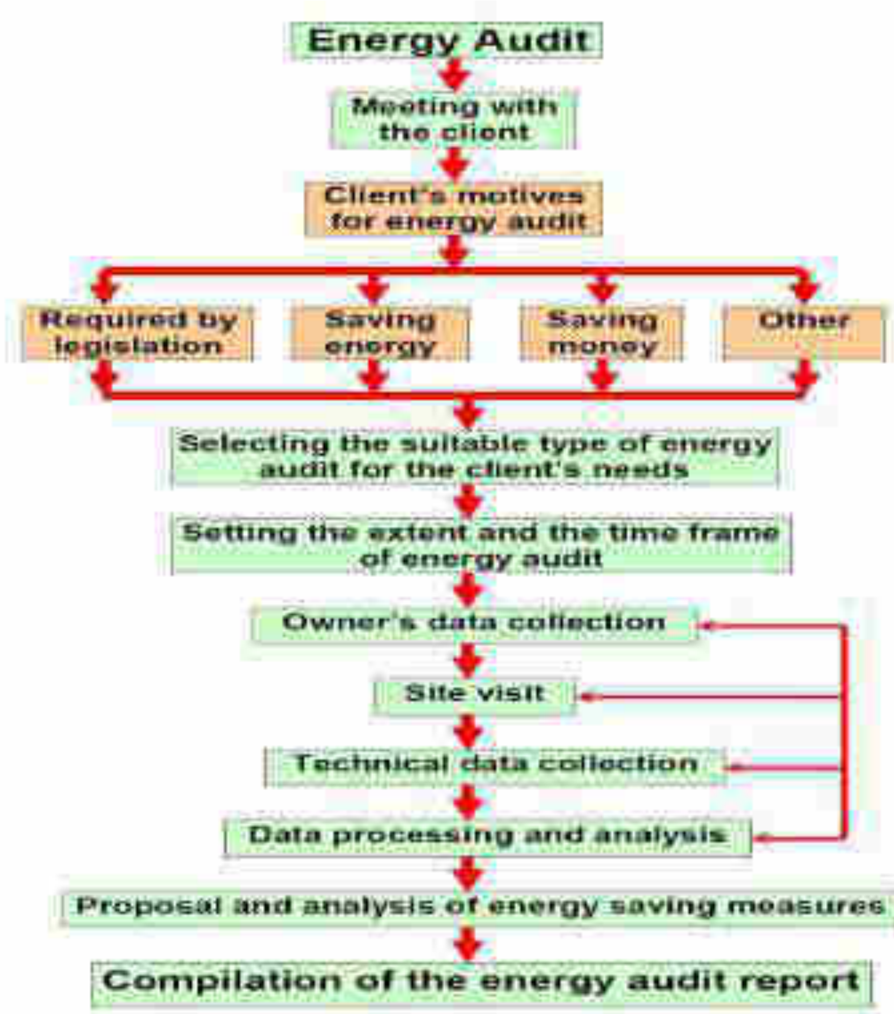


Fig: 5.28 Steps in Energy Audit

(Image source: Petroleum Conservation Research Association)

5.12HYDROCARBON VISION-2025

The Hydrocarbon vision 2025 visualises Indian hydrocarbon sector to be a globally competitive industry benchmarked with the best in the world and promoting healthy competition in the market.

- By the year 2025, petroleum product demand would go up 4 times to about 370 million tons per annum.
- Refining capacity would go up from 112 to about 360 million tonnes at a cost of Rs 2500 billion.

- Pipeline capacity requirement would go up from 30-170 million tonnes at the cost of Rs 210 billion for transportation of about 45 percent of petroleum fuels.
- Storage capacity requirement would go up from 9-27 million tonnes, at the cost of over Rs 160 billion.
- The investment needed to set up retail outlets for the sale of about 133 million tonnes per annum of motor gasoline and diesel is estimated at Rs 930 billion.

NATIONAL ELECTRIC MOBILITY MISSION PLAN:

The National Electric Mobility Mission Plan (NEMMP) 2020 was launched by the Government of India in 2013 with the objective of achieving national fuel security by promoting electric and hybrid vehicles. The target is to achieve sales of 6 – 7 million in the hybrid and electric vehicles sector from 2020. The government will provide fiscal and monetary incentives for this industry. The expectation is that crude oil worth Rs.62000 crore will be saved due to this.

Under the NEMMP, the government has launched the Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME India) scheme.

- This scheme had an initial outlay of Rs. 75 crore.
- This scheme is expected to provide a major thrust towards early adoption of electric and hybrid technologies.
- The government hopes that such vehicles will become the first and natural choice of consumers thereby slowly replacing conventional vehicles, thus helping India inch towards a pollution-free environment.
- The government envisions that by 2020, early market development via demand incentive, domestic production and in-house technology development will help this industry reach self-sufficient economies of scale.
- In 2012-13, around 42000 electric vehicles and close to 20000 hybrid vehicles were sold in India. Most of the electric vehicles were low-speed scooters. It is expected that with the government push for this sector, the market can be extended for 2 Wheeler, 3 Wheeler, 4 Wheeler, LCVs and buses.
- The government has plans to incentivise buyers buying hybrid and electric vehicles by offering monetary support. The incentive will be disbursed through an electronic mechanism or portal.

- Under this scheme, the producer of the vehicle will reduce the price of the vehicle while selling to the consumer and the same amount will be reimbursed to the manufacturer by the government.

Note: The latest update on the scheme: the government has withdrawn the subsidy given to mild-hybrid vehicles.

Four focus areas of FAME India:

Technology development	Pilot projects
Demand creation	Charging infrastructure

The NEMMP 2020 is an important scheme under the Government of India.

ENERGY STORAGE SYSTEMS:

It is a well-known fact that the intermittent nature of power supply which is provided by renewable energy sources like wind or solar create a necessity for efficient and scalable ways to store and supply electricity so that when the wind stops flowing and the sun stops glowing, even then the operators are able to provide a steady stream of power for uninterrupted use.

In this light it is necessary technologies that are being developed for storing electricity at a large scale;

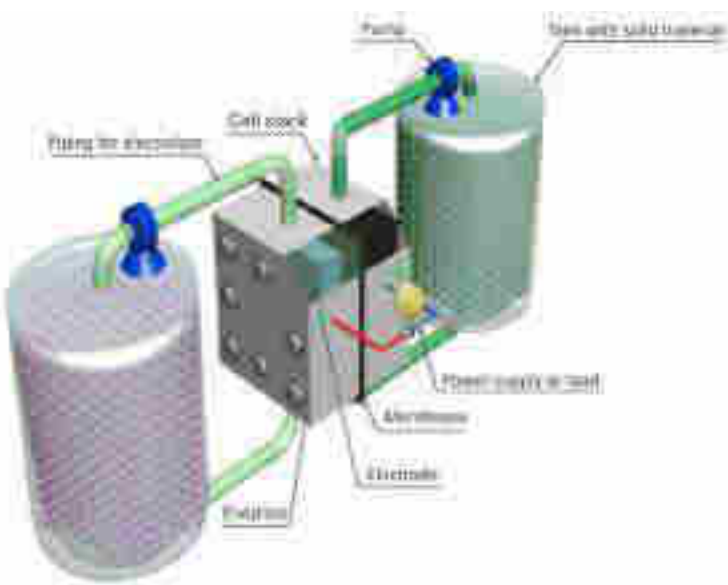
Batteries

Large scale batteries are the most common example of energy storage systems. the recent ongoing innovations have improved the scalability , reliability and capacity of batteries ,thus, there has been improved longevity of the batteries for storage of energy.

Lithium-ion batteries are the most widely used form of batteries. The flexibility and the reliability of the technology is a huge benefit that makes these batteries superior in many ways to other forms of rechargeable batteries, and for that reason its developers - Dr. M. Stanley Wittingham, Dr. John Goodenough and Dr. Akira Yoshino - were awarded this year’s Nobel Prize in Chemistry.

These batteries have flexibility of Technology which makes them an important component of vehicle industry system, where they can be adapted as small high-power batteries for hybrid power buffering, to medium power batteries that can provide both electric power and buffering in plug-in hybrids, to the increasingly effective high-energy batteries in electric-only vehicles.
There are several advantages of lithium-ion batteries, which is why in a 2016 study it was found that this technology accounted for 95% of deployed systems in the grid-scale battery market. But there are certain demerits as well which is driving demand for other kinds of storage systems. Some of the issues associated with these batteries are; significant cost of production, laser efficiency for long term storage, also they can have robustness issues, with batteries liable to explode if damaged. Over time they will also degrade and require replenishment.
Lithium itself is a relatively rare mineral that must be mined at increasing costs, so also, there are sustainability issues with the disposal of batteries.

Hence, for these reasons there has been an increased push in the development of alternative batteries, with a rise in other forms in grid-scale developments over the last two to three years.

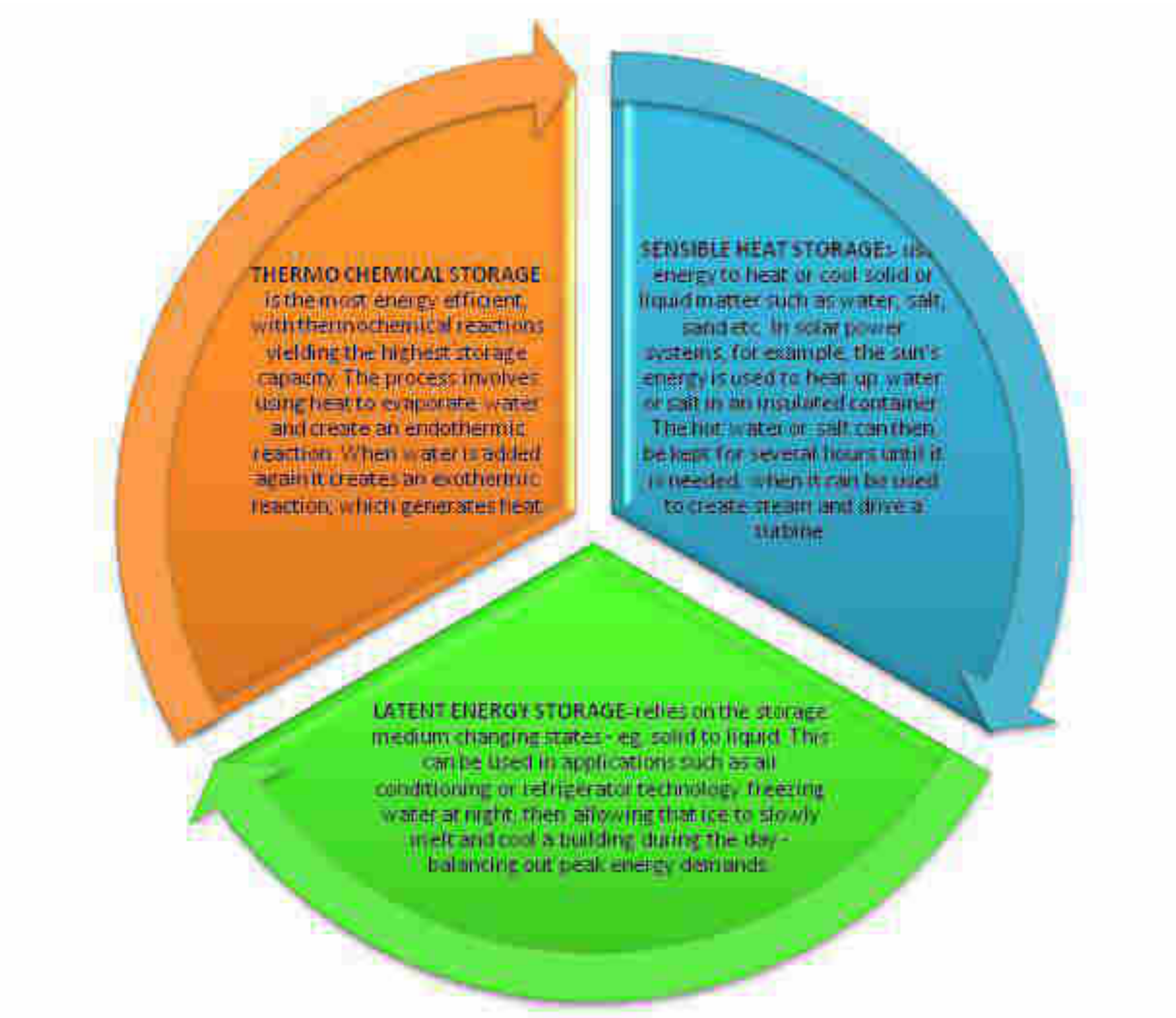


(Image source: Singapore university)

Thermal Energy Storage

Thermal energy storage converts energy into heat that can be reused at a later time. The basic process that it undergoes is relatively simple compared to the complex chemical processes that make up batteries, but the solutions at scale can require huge construction projects.

There are three main forms of thermal energy storage systems



Mechanical Heat Storage

Mechanical energy storage systems use kinetic or gravitational forces to store energy. Since generators use the movement of a turbine to generate electricity, these systems harness the potential force to drive that turbine for a later date.

Like thermal energy storage, it's based on a relatively simple theory, but produces some complex and imaginative results. In its simplest form it can take the shape of a weight and pulley, with the energy required to lift the weight stored as gravitational potential until it is released again. But more ambitious ideas are required in order to store grid-scale energy.

Hydrogen Energy Storage

Energy can be stored through the electrolysis of water, which separates hydrogen and oxygen molecules. Hydrogen can then be stored and then used to generate electricity in much the same way as fossil fuels - but without any emissions. It's also used effectively in fuel cells for the automotive sector.

When used in a small scale, hydrogen can be stored in pressurised vessels. But for large scale projects it is stored in underground salt caverns of up to 500,000 cubic metres, at pressures of 2,900 psi. A cavern at this size and pressure would deliver a capacity of around 100 GWh of stored electricity.

CHAPTER 6: NUCLEAR TECHNOLOGY

INTRODUCTION

Homi Jahangir Bhabha fostered the development of the Indian nuclear program and as a result of his vision and the work of several scientists in the field, India is the only developing country that is self-reliant in nuclear technology. This is despite the presence of many international technology control regimes in the nuclear arena.

The genesis of nuclear science in India can be traced back to the establishment of the Tata Institute of Fundamental Research (TIFR), in Bombay in 1945, by Homi Jahangir Bhabha. Since then India has been making rapid strides both domestically and at the global stage in nuclear science research and technology. Today it has harnessed the arena of nuclear technology for the generation of electricity and also nuclear techniques have been used in the field of medicine, agriculture, industry among others.

6.1 DEPARTMENT OF ATOMIC ENERGY (DAE)

The Department of Atomic Energy, responsible for the development of nuclear power technology in India, was formed on 3rd August 1954.

Apart from developing nuclear technology, the DAE is also in charge of developing radiation technology for applications in the fields of medicine, industry, agriculture and basic sciences.

Department of Atomic Energy (DAE) was established with the following objectives:

- Generating electricity from nuclear energy through the use of the naturally available uranium and thorium in India
- Building research reactors and implementing the radioisotopes produced in reactors for application in the fields of agriculture, industry and medicine
- Developing advanced technology in domains like lasers, accelerators, information technology and biotechnology
- Developing materials including strategic and non-nuclear ones like titanium
- Playing a role in national security
- Contributing to industrial development by promoting technology transfers and interaction with the industry
- Offering support to fundamental research in nuclear energy and other areas in science

- Coordinating with academic institutions to enhance the quality of education and research and also offering research grants to these institutions
- Promoting international collaboration in fields of advanced research and big science projects.

The apex body of the DAE is the Atomic Energy Commission (AEC)

The DAE is headquartered in Mumbai. The department executive is the Chairman of the AEC, who is the ex-officio executive head of the department. This department is directly under the Prime Minister of the country.

This department has 6 research institutions, 5 public sector companies, 3 industrial organizations, 3 service organizations and 3 universities under it. The DAE also supports many other research institutes of eminence in India.

NUCLEAR ENERGY

Nuclear Energy is the energy at the core of an atom. Normally, the mass of an atom is concentrated at the center of the nucleus. Neutrons and Protons are the two subatomic particles that comprehend the nucleus. There exists a massive amount of energy in bonds that bind atoms together.

Nuclear Energy is discharged by nuclear reactions either by fission or fusion. In nuclear fusion, atoms combine to form a larger atom. In nuclear fission, the division of atoms takes place to form smaller atoms by releasing energy. Nuclear power plants produce energy using nuclear fission. Sun produces energy using the mechanism of nuclear fusion.

Nuclear Reactions

- Nuclear reactions convert one element into a completely different element.
- Suppose if a nucleus interacts with any other particles then separates without altering the characteristics of other nuclei then the process is called **nuclear scattering** rather than specifying it as a nuclear reaction.
- This does not imply radioactive decay.

- One of the most evident nuclear reactions is the nuclear fusion reaction that occurs in fissionable materials producing induced nuclear fission.

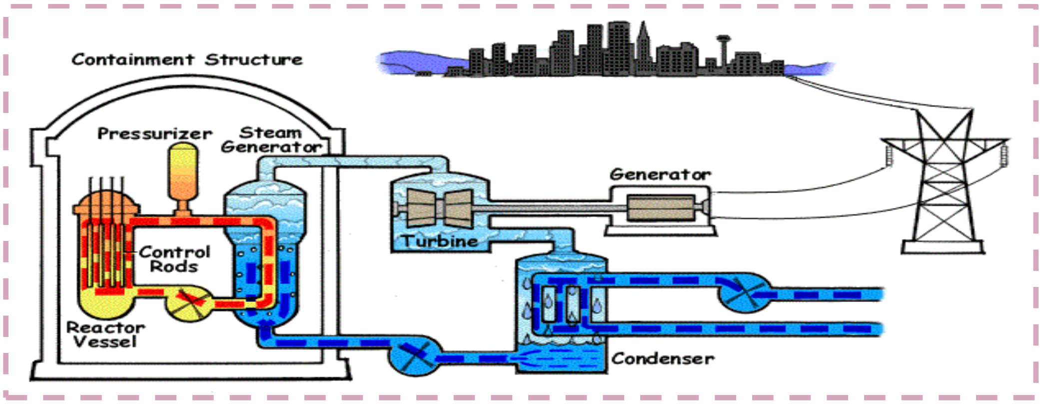


Fig 6.1: Nuclear Energy Cycle

Source: BYJUS

Applications of Nuclear Energy

- Nuclear medicine
- Nuclear Technology is used in Industries
- Agricultural uses of nuclear technology
- Environmental uses of nuclear technology
- Biological Experimentations
- Medical diagnosis and treatments
- Scientific Investigations
- Engineering Projects
- Neutron Activation Analysis

6.2 NUCLEAR POWER IN INDIA

Currently, India is having 22 Nuclear Reactors that are operational in the 7 nuclear plants, having a total installed capacity of 6,780 MW. Nuclear power supplied around 4% of electricity in India in year 2018. Seven more nuclear reactors are under construction with a cumulative generation capacity of 4,300 MW.

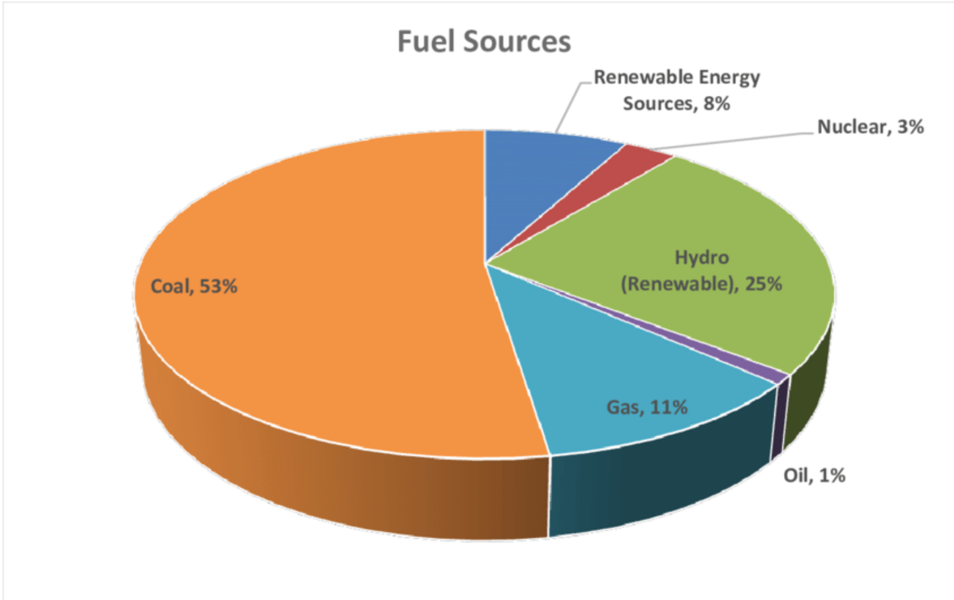


Fig 6.2: Share Of Nuclear power in India

(image source:india energy portal)

NUCLEAR POWER PLANTS
• Tarapur Atomic Power Station (TAPS), Maharashtrais operated by Nuclear Power Corporation of India Limited (NPCIL) has a capacity of 1400 MW • Rawatbhata Atomic Power Station (RAPS), Rajasthan is operated by NPCIL. It uses a Pressurized Heavy Water Reactor (PHWR) and has a total capacity of 1180MW. • Madras Atomic Power Station at 440 MW capacity. • Kudankulam nuclear power plant, Tamil Nadu is operated by NPCIL. The plant has a capacity of 2000MW and uses Water-Water Energetic Reactor (WWER) that is based on a series of designs of pressurized water reactor • Kaiga generating station, Karnataka is operated by NPCIL. Its total capacity is 880 megawatts. • Narora Atomic Power Station in (NAPS), Uttar Pradesh is operated by NPCIL. Its total capacity is 440MW • Kakrapar Atomic Power Station (KAPS), Gujarat with 880MW capacity

Fig 6.3: Atomic Power Stations

(Image source: Philophysics forum)

One of the main reasons for the low capacity factors of nuclear power in India is lack of nuclear fuel. India has been making advances in the field of **Thorium based fuels** and trying to design and develop a prototype for an atomic reactor using thorium and uranium (low enriched), which forms a key part of the 3 stage Nuclear programme of India. The country has also recently re-initiated its involvement in the low energy nuclear reaction research activities, in addition to supporting work done in the fusion power area through the International Thermonuclear Experimental Reactor initiative.

The Government of India has made nuclear energy its priority, and intends to augment the share of Nuclear Energy in total energy generation from around 3.5% to 25 % by the year 2050. Recently, India has been trying to ramp up its capacity for nuclear generation and for this it has also been supported by its strategic partners such as USA, AUSTRALIA, JAPAN among Other nations.

6.3 NUCLEAR POWER PROGRAMME

India's 3 stage Nuclear Power Program was conceived soon after Independence to meet the security and energy demands of Independent India. India's Uranium reserves constituted a very small amount, but India has a very huge amount of thorium reserves. Hence to attain independence in the energy domain it was conceived to develop a 3 stage nuclear power program utilising the abundant thorium reserves.

India's 3 stage Nuclear Power Program was devised in 1954.

Locations of Nuclear Power Plants – Planned in India

- Gorakhpur
- Chutka – Madhya Pradesh
- Mahi Banswara – Rajasthan

Locations of Nuclear Power Plants – Proposed

- Rajouli, Nawada – Bihar
- Bhimpur – Madhya Pradesh
- Jaitapur (Ratnagiri District) – Maharashtra
- Kovvada (Srikakulam District) – Andhra Pradesh
- Nizampatnam (Guntur District) – Andhra Pradesh
- Pulivendula (Kadapa District) – Andhra Pradesh
- Chhaya – Mithi (Bhavnagar District) – Gujarat

Locations of Uranium Resources

- Tummalapalle (Kadapa District) – Andhra Pradesh
- Nalgonda District – Telangana
- East Singhbhum District – Jharkhand
- West Khasi Hills District – Meghalaya
- Udaipur District – Rajasthan
- Yadgir District – Karnataka
- Rajnandgaon (District) – Chhattisgarh
- Sonbhadra District – Uttar Pradesh
- Rudraprayag District – Uttarakhand
- Una District – Himachal Pradesh
- Gondia District – Maharashtra

Rationale for the three stage Nuclear Programme:

- India has only 2% of World's Uranium reserves, on the other hand, India has 25% of the World's Thorium reserves.
- Since India was not part of some of the International Nuclear treaties, India was prevented from taking part in international trade in the nuclear field.

- India has a huge population and growing economy, to meet the energy demands India had to rely heavily on imports of coal, and crude oil.
- Hence India had to devise methodologies to be self-sufficient in meeting energy demands arising due to a burgeoning population and economy; the 3 stage Nuclear Power Program was one of the answers to it.

Thorium is not a fissile material, but it can be converted into Uranium – 233, which can then undergo fission to produce energy.

STAGE-I OF NUCLEAR POWER PROGRAM

For the 1st stage the Reactors that were chosen was a Pressurised heavy water reactor (PHWR). However to gain operational experience initially and atomic power station comprising two Boiling water actors (BWR) was set up at Tarapur (Maharashtra)

Later on the first two Pressurised heavy water reactors (PHWR) at Rawatbhata started commercial operations in 1973 and 1981. While the first unit of the reactor was built with the help of Atomic energy of Canada limited, the second unit was completed with the indigenous research and development efforts and with the support of Indian industry. Due to this success, a number of reactors were commissioned in India.

A pressurized heavy water reactor is a reactor that commonly uses unenriched natural uranium as its fuel, while it uses heavy water as its coolant and moderator. The heavy water coolant is kept under pressure allowing it to be heated to high temperatures without boiling much as in a Pressurised water reactor.

6.4 NUCLEAR FUEL CYCLE

Nuclear Fuel Cycle is an array of an industrial process which includes a production of electricity from uranium in nuclear reactors. It can be defined as various activities that are related to generating electricity from nuclear reactions. Nuclear fuel cycle also termed as nuclear chain reaction comprises a front end, service period and back end. The front end consists of steps that are necessary for preparation of fuel, service period involves steps in which fuel is utilized during the time span of a nuclear reactor, and back end comprises steps that are essential for managing, conversion or disposal of used fuels. If used fuel is not converted for reuse then the process is defined as an open fuel cycle. If used fuel is converted for reuse then the process is described as a closed fuel cycle. Let's consider uranium. It is placed in a reactor for an average of three years to generate electricity. Once the electricity is produced, used fuel further undergoes various steps that are mentioned above.

6.5 URANIUM

Uranium is found in rocks, rivers, sea water and in most of the solids. It is one most slightly radioactive metal. In most of the places in the world, the concentration of this metal is adequately high in the ground. They are extracted and used as a nuclear fuel.

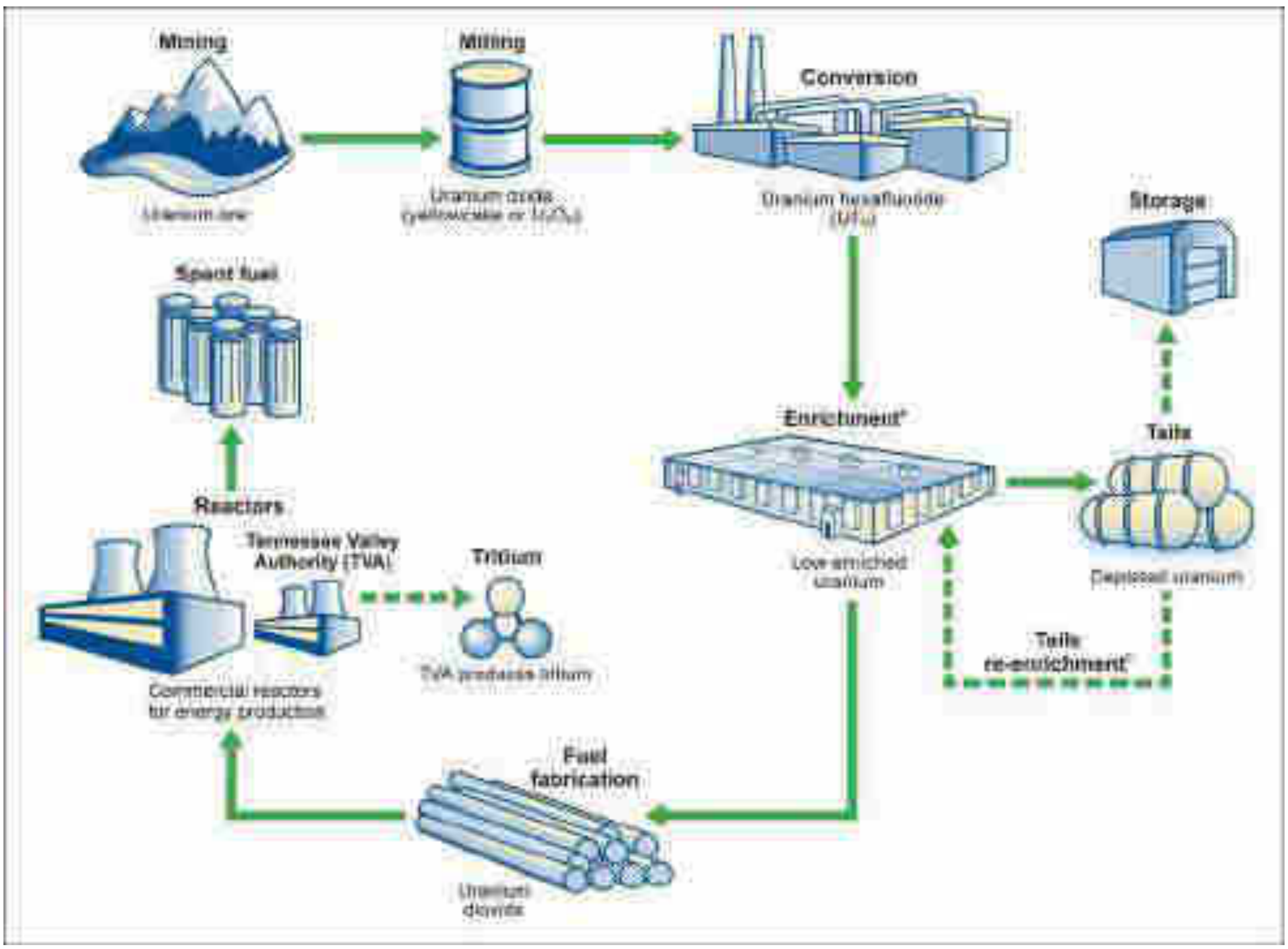


Fig 6.4 :Fuel Cycle

(Image source: Byjus)

Uranium Mining	Uranium Milling	Conversion of Uranium
Two methods are used to recover uranium ore, evacuation, and situ techniques. Evacuation may be open pit mining. The Situ process involves oxygenated groundwater that is circulated through the pores of an orebody to soften uranium oxide and to bring it to the surface. The convention mill is used to restore uranium oxide from a solution.	It is carried out near to the site of a uranium mine. A majority of mining facilities involve a mill; wherein a single mill can process ores from several mines. Milling involves a production of uranium oxide concentration that is carried out from the mill.	It includes the conversion of uranium oxide into uranium hexafluoride. This product only consists of natural uranium, not the enriched product. Uranium hexafluoride is converted in gaseous form at a moderate temperature of 57 °
Enrichment	**Fabrication**	**Power Generation**
The concentration of U-235 is less than a requirement to sustain a nuclear chain reaction. Hence it has to be enriched in fissionable isotopes and it is carried through two processes namely low-enriched uranium and simply depleted uranium.	In this process, uranium dioxide is converted into pellet form. The pellets are fired at a very high temperature to form enriched uranium and then undergo a grinding process. These pellets are connected through metal tubes organized in a fuel assembly to assure consistency in the fuel.	The core of a reactor is made up of several hundreds of fuel assemblies. U – 235 isotopes split producing an excess of heat. This process is known as a chain reaction and it entirely depends upon the type of moderator namely graphite or water

Note:- In some countries depending upon the policies, used fuels may be shipped into central storage facilities.

FUEL REPROCESSING

The indian nuclear power program is based on a closed **fuel cycle** under which the spent or used fuel namely **Plutonium** or **U-233** is recycled. Right since the inception of the programme the Department of Atomic Energy has been developing the technology of fuel REPROCESSING.

There are pilot plants for fuel reprocessing at Trombay, that reprocess fuel from research reactors and industrial scale plants at Tarapur and Kalpakkam that reprocess fuel from power reactors.

STAGE -II OF NUCLEAR PROGRAM(FAST BREEDER REACTORS)

- This stage of nuclear power program consists of Fast Breeder Reactors (FBRs). These reactors use Plutonium-239 which is recovered as a byproduct from First Stage and natural Uranium for fuelling the reactor.
- In FBR, the Plutonium 239 undergoes fission and produces energy. The Uranium-238 present in the fuel gets converted into additional Plutonium-239 by absorbing a fast moving neutron.
- The FBR use produces more fuels than what is spent, that is: for every 1 kg of plutonium spent, around 1.1 kg of Pu-239 is produced as a byproduct.
- After building sufficient reserves of Plutonium-239, thorium can be used as a blanket material inside the reactor which gets transmuted to U-233 to be used in the third stage.
- The surplus Plutonium-239 that is produced in each Fast breeder reactor can be utilised for setting up more FBRs.

The first prototype FBR has been built at the Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam, Tamil Nadu which achieved criticality in 2019. It has been utilising Uranium -Plutonium carbide fuel.

Based on the above experience the Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVINI) is building a 500 MW pool type reactor using a mixed Uranium - Plutonium Oxide fuel

For achieving 2500 MW of electricity capacity from five FBRs, Construction of four more FBRs has been planned

STAGE - III NUCLEAR POWER PROGRAM (THORIUM BASED REACTORS)

Thorium utilisation is the core objective of the Nuclear power program of India.The Thorium based reactors will be thermal breeder reactors which can be refueled with naturally occurring thorium after the initial fuel charge.

Large scale deployment of thorium based reactors can only be expected after 3-4 decades of commercial operation of fast breeder reactors. Due to the large delay for direct thorium based nuclear power programme, India is looking for reactor designs which could allow direct use of thorium in parallel with a sequential three stage programme. However beginning has already been made by introducing forum uranium cycle in Pressurised heavy water reactors and research reactors.

India is considering three options in the development of thorium based reactors that include

- Accelerator Driven Systems (ADS),
- Advanced Heavy Water Reactor, (AHWR)
- Compact High Temperature Reactor.

Advanced Heavy Water Reactors are to be fuelled with 20% Low Enriched Uranium (LEU) and 80% Thorium. Low enriched uranium is available in the world market which can be utilised in these reactors.

Moreover the research reactor at KALPAKKAM MINI REACTOR (KAMINI) utilises uranium fuel which is derived from Thorium, in radiography of various materials.

For the separation of Uranium-233 from irradiated thorium fuel on a plant scale,a Uranium-Thorium separation facility is in operation at Trombay.

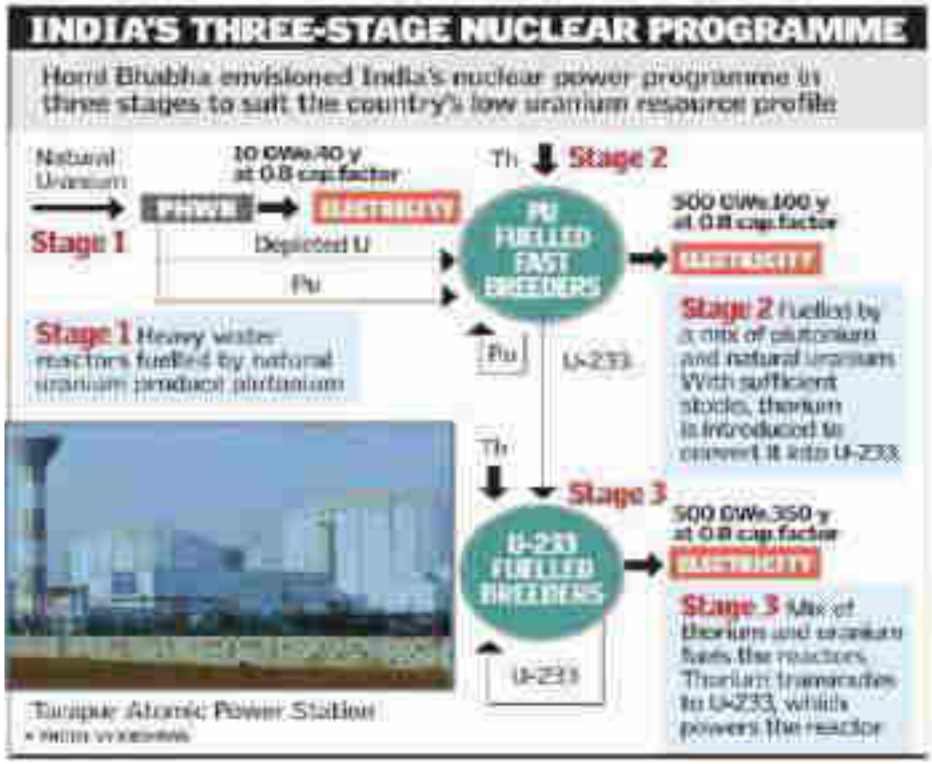


Fig 6.5: Three Stage Nuclear programme

(Image source: The Hindu)

Limitations/Challenges in development of Thorium based reactors

Thorium cannot sustain the chain reactions by itself and constantly requires fissile material like uranium or plutonium for transmuting Th-232 to U-233.Shortage of Uranium fuel which is required for converting the fertile fuel thorium into fissile fuel capable of sustaining a chain reaction is the biggest obstacle for the development of thorium fuelled reactors in India.

INDIA AT CERN
Indiahas had some of the biggest contributions to CERN,and is involved in various programmes like computing, power supply systems, hi-tech components, and high precision mechanics.Of the total 18000 scientists working with CERN from from all over the world, around 400 are from India and India has major contributions in all the experiments: ranging from the the Large Hadron Collider, the ATLAS ,compact muon solenoid and the ALICE experiments.india had associations with CERN since the 1970s, while eit became an associate member in 2017.

Also India has increasingly contributed to the different mega science projects like International Thermonuclear Experiment Reactor (ITER), Large Hadron Collider (LHC) at CERN, the Square Kilometer Array (SKA) and the India based Neutrino observatory and the LIGO.

Large Hadron Collider (LHC):

During the making phase of Large Hadron Collider (LHC): Indian scientists have been involved in the design of many components of the LHC, whereas construction of those took place by scientists and engineers through Indian industries. Some of them include superconducting corrector magnets, precision magnetic positioning system jacks, accelerator protection systems, quench detection electronics, vacuum system design for long beam transport lines and cryogenic systems.

ALICE EXPERIMENT:

ALICE experiment: Indian scientists have played a significant role in the ALICE experiment, which is a dedicated experiment for search and study of Quark Gluon Plasma (QGP). Hardware contributions to the ALICE detector include the Photon Multiplicity Detector (PMD), the Muon Spectrometer, the MANAS chip, and Silicon pad detectors. The PMD is a fully Indian effort from conception to commissioning. The QGP research program of ALICE is on the quest to get a glimpse of how matter behaves within a few microseconds after the birth of our Universe. Indian scientists have contributed to the physics analysis, which led to the discovery of the QGP matter and its characterization.

CMS - India:

CMS experiment: Indian scientists have played a major role in the CMS experiment, which is one of the two experiments that discovered the Higgs Boson. Our scientists have been involved in the design and manufacture of the Hadron Barrel Outer Calorimeter; Silicon strip based pre-shower detector and RPC detectors, which were installed recently. Indian scientists have contributed to the physics analysis that led to the discovery of Higgs Boson and a detailed study of Quark-Gluon Plasma, a form of matter in the early Universe.

WLCG: INDIA;

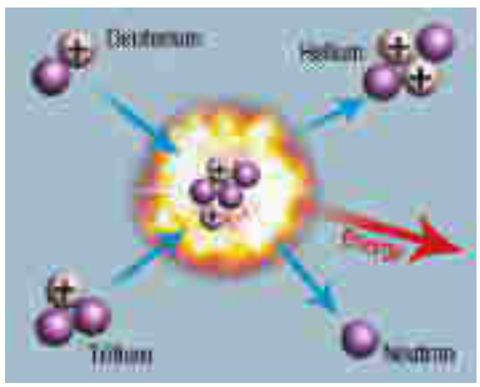
GRID computing: Experiments at CERN produce colossal amounts of data (roughly 30 petabytes a year), which are processed using Grid computing, enabling sharing of resources belonging to computer centers located around the world. Indian scientists have contributed substantially to the building and operation of the Large Hadron Collider Grid (LCG). LCG has a hierarchical structure of data dissemination, of which India hosts two Tier 2 centres at Variable Energy Cyclotron Centre (VECC) and Tata Institute of Fundamental Research (TIFR), in addition to several Tier 3 centers. The two Tier-2 Grid computing centres at VECC and TIFR are performing a large part of LHC computing.

6.6 NUCLEAR FUSION

Nuclear fusion is the process where the nuclei of two light atoms combine to form a new nucleus. This is another way of producing nuclear energy, like nuclear fission, although in nuclear fission the nucleus of a heavier atom splits. Now let us learn how the energy is produced by nuclear fusion.

When two light nuclei combine in a fusion reaction, the combination has a mass that is less than the mass of the initial individual nuclei. This means that the reaction gives out energy according to Einstein's mass-energy equivalence.

An example of a fusion reaction is that of the combination of Deuterium and Tritium, which are isotopes of Hydrogen to give Helium and release a neutron and give out around 17 MeV of energy.



<u>Fig 6.6 Nuclear Fusion</u>

(image source:byjus)

Nuclear binding energy: It is defined as the energy required to split the nucleus of an atom into its components.

Nucleon: It is defined as one of the subatomic particles i.e; proton or a neutron.

Fusion: It is defined as a nuclear reaction in which the nuclei combines to form a massive nuclei with release of neutrons and energy.

NUCLEAR FUSION REACTORS

There are several research projects and experimental reactors which are under test and being funded by Private and Public sectors. Some of these new fusion projects are utilising the newest generation of supercomputers for better understanding and tweaking the behavior of the ultrahigh-temperature plasma in which hydrogen nuclei fuse to form helium. Others have reopened promising lines of inquiry that were shelved decades ago. Still others are exploiting new superconductors or hybridizing the mainstream concepts.

Few of these new experimental projects are as under:

Magnetic Confinement

Here, the hot plasma is checked from touching the walls of the confining material by use of magnetic fields. The temperatures achieved are extremely high and therefore they are kept from touching material.

However this technology is still at a nascent stage and scientists are a long way from achieving a self-sustaining reaction, and from preventing neutron activation from destroying the reactor's walls.

Inertial Confinement

Here, the high energy density is put into a small pellet of reactors fusing them in such a short span that they don't have the time to touch the confining material. Powerful pulsed laser or ion beams compress a small fuel pellet to extremely high densities, and the resulting shock wave heats the plasma before it has time to dissipate.

But there are issues with this type of fusion because the forces exerted on the fuel pellet result in laser-plasma instabilities that produce high-energy electrons, which heat and scatter much of the fuel before it can fuse. Moreover due to the high cost of laser and several complexities associated with it makes the traditional approaches to Inertial Confinement unsuitable for energy production.

Magnetic Inertial Fusion

Also known as Magnetized Target Fusion,this is a hybrid approach which uses magnetic fields to confine a lower-density plasma (as in magnetic-confinement fusion),that can be heated and compressed using an inertial-confinement method such as lasers or pistons (as in inertial-confinement fusion). But in order for this technique to work the scientists are yet to find a way to increase the plasma density at a working level and keep it there so long enough that a significant fraction of the fuel mass gets fused.

Stellarator

The stellarator's spiraling ribbon shape produces high-density plasma that's symmetrical and more stable than a Magnetic Confinement Reactor, allowing the reactor to run for long periods of time. But the challenge with this kind of reactor is its design which is hard to be built and extremely sensitive to imperfect conditions.

However, some of the groups involved in building these reactors are predicting significant fusion milestones within the next five years, including reaching the breakeven point at which the energy produced surpasses the energy used to spark the reaction. As the threat of climate change looms large over the world it is imperative that one of these projects gets commercialized and succeed in order to mitigate harmful effects of climate change and simultaneously fulfill the energy requirements of a large scale population.

6.7 ADVANTAGES AND DISADVANTAGES OF NUCLEAR FUSION

Advantage

It is a safe source for the generation of electricity.	It is economic and sustainable.	The amount of fuel available in nature is abundant and is inexpensive.	The greenhouse gases produced during the process of fusion is minimal.

Limitations of Nuclear Fusion Technology

There have been several efforts by the government of most of the developed Nations like the USA ,France ,Germany etc but there were project delays and cost overruns which came as a setback to most of the governments.
Although there is abundant fusion energy in nature, in the form of thermonuclear fusion which powers stars and the sun, the task of triggering and controlling a self-sustaining fusion reaction and harnessing its power is arguably the most difficult engineering challenge humans have ever attempted.
Also most of the challenges arise in fusion energy due to issues with heating, containing and controlling the plasma. The neutron radiation in a nuclear fusion reactor damages the reactor's walls which must be replaced frequently and disposed of as low-level radioactive waste.

Nevertheless,several of the new initiatives mentioned above are underway to overcome the challenges and run few concept projects on Nuclear fusion energy in order to materialise the envisaged dream into a reality.

NUCLEAR FISSION

Nuclear fission is the process of splitting a heavy nucleus, such as uranium or plutonium, in two smaller nuclei of nearly the same mass. During this process, the unstable radioactive nucleus is split into two smaller nuclei. Nuclear fission can occur spontaneously in some cases or can be induced by the bombardment on the nucleus with a variety of particles (e.g., protons, or neutrons or alpha particles) or by gamma rays radiation.

During this fission process, a huge amount of energy is produced further giving rise to radioactive elements as well as the release of many neutrons. These neutrons can further induce chain fission reaction in the nucleus of the uranium or plutonium and release more neutrons. This can result in an uncontrolled chain reaction till all the starting material is exhausted where a large amount of energy is also produced.

If such reactions can be controlled in a nuclear reactor, these chain reactions can be harnessed to meet the electricity needs of society. On the other hand, such uncontrolled reactions can lead to the formation of atom bombs, which can be very devastating.

The modern “Atomic Age” is attributed to the discovery and developments in the field of nuclear fission. This has its own boon and bane. It’s judicious usage and development can help us to develop at a great speed and in a sustainable manner but if it falls in the wrong hands it can cause a great threat to humanity. However, there is still a great scope of development and research in this field and still many more questions are to be answered.

As mentioned above the splitting of neutrons results in the release of a large amount of energy. During this process, there is a strong repulsion force between the protons. But, they are also bound together by the strong nuclear force. Typically, each proton applies a repulsion force of 20N on every other proton and that is equal to the force of a hand resting on a person’s lap. This is really a very large force for these atomic particles.

Due to such a large force inside the small nucleus, it leads to the production of a large amount of energy and is enough to cause a considerable reduction in mass. This implies that the total mass of each of the fission fragments is less than the mass of the starting nucleus. Here the missing mass is called the mass defect.

It is easy to understand the amount of energy that binds all the nuclei together. Every nucleus has this binding energy except hydrogen. Therefore, the binding energy available to each nucleon is simply called the binding energy per nucleon. The same amount of energy is actually required per nucleon to split a nucleus.

The products formed after fission are more stable means further splitting is very hard. As this binding energy for fission products is very high, the nucleonic mass becomes lower. The result of this large binding energy and lower mass results in the release of energy. Nuclear binding energy and mass defects are also used interchangeably.

When a nucleus fissions reaction takes place, the neutron breaks the target nucleus into further smaller products. These fission products are nearly equal to half the original mass. Two or three neutrons are also emitted.

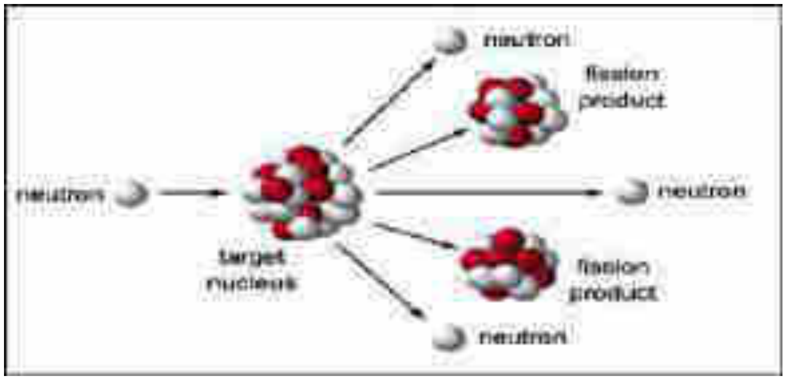


Fig 6.7 Nuclear Fission

(image source:byjus)

NUCLEAR FISSION REACTION

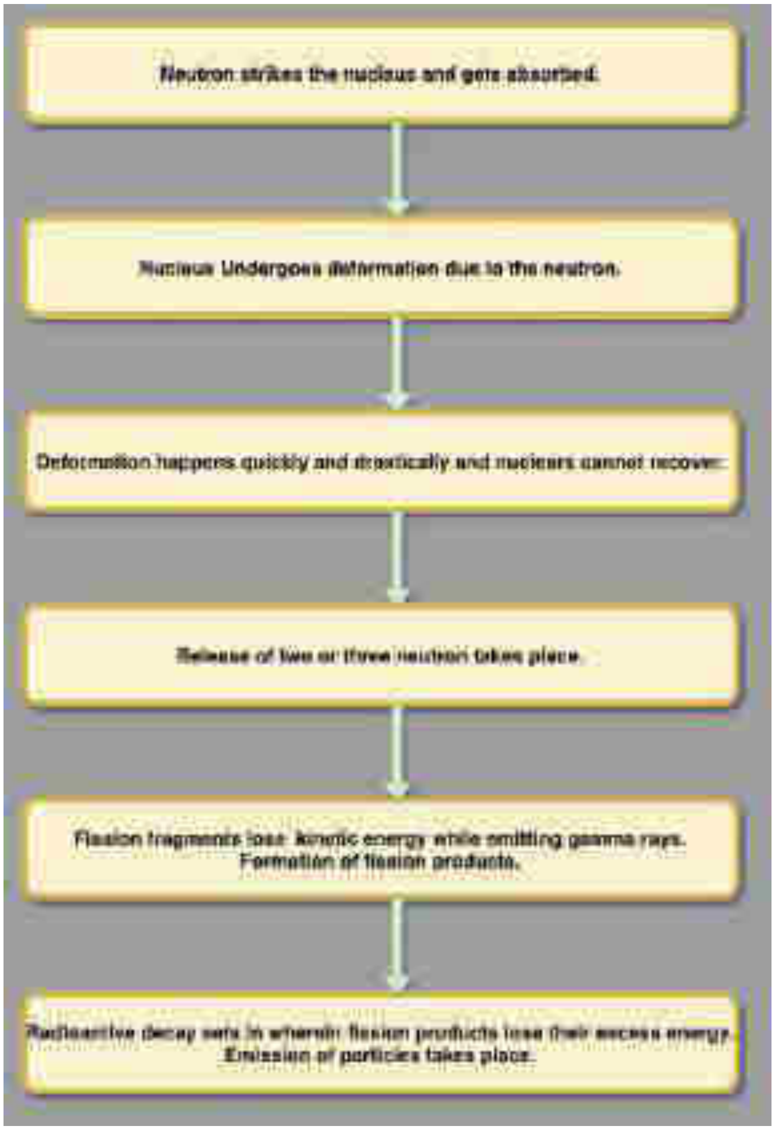


Fig 6.8 Steps in Fission Reaction

(image source:byjus)

Nuclear Fission Reactor

A nuclear reactor is the most important part of a nuclear power plant. This is the place where nuclear chain reactions occur that produce energy by fission. The heat thus produced can be used to produce electricity.

The main purpose of a reactor is to contain and control energy released. Uranium is used as the nuclear fuel in the reactors. The uranium is treated with ceramic pellets and they are sealed in the form of metal tubes called fuel rods. Generally, about 200 such rods are assembled together to form a fuel assembly. When a hundred of such assemblies are assembled together, it is called the core.

The fuel rods are dipped in water in the reactor, which functions as both a coolant and moderator. The job of the moderator is to slow down the neutrons produced by fission to control the chain reaction. Control rods may be immersed in the reactor core to reduce the reaction rate or pulled out to increase the same. The heat produced by such reactions converts the water into steam, which is further converted into carbon-free electricity by the help of turbines.

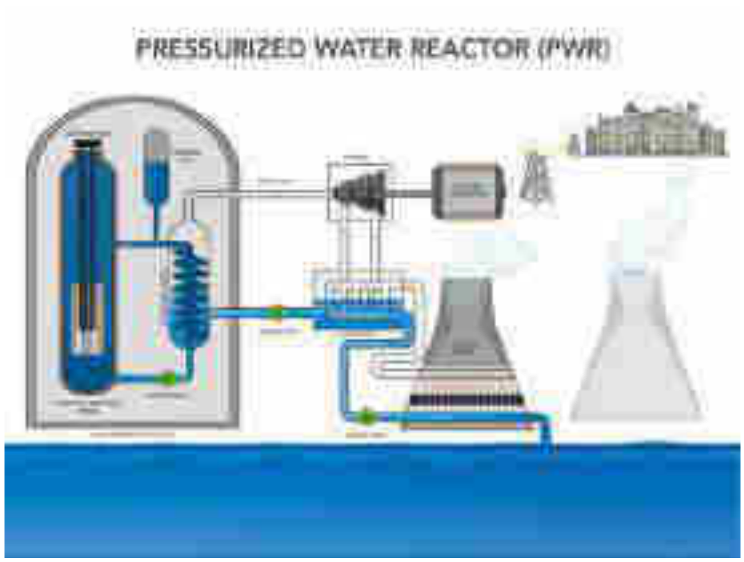


Fig 6.9 Nuclear Fission Reactor

(image source; byjus)

Advantages

- Clean Alternative Source of Energy:-Nuclear fission is one of the most researched and well-known topics of nuclear technology. This has been utilized as a very clean alternative source of energy. It will not be a hyperbole if we tell it as “the energy source of the future”. This technology is now achieving perfection and excellence and emerging at a very fast pace compared to other alternative sources of energy.

- **Fulfil The Needs Of The Present And Future Generation:**An enormous amount of energy is produced by the process of nuclear fission, which can be utilized to fulfil the needs of next-generation high tech cities, and industries. As this is a very rapid reaction, energy can be produced depending on the requirement with greater reliability.
- **Reduced Threat From Greenhouse Gases Production And Global Warming:**In contrast to fossil fuels, which causes serious damage to the environment, nuclear fission produces energy without releasing greenhouse gases into the atmosphere, which reduces the effects of global warming and even helps fight pollution.
- **Extremely Low Operation Cost:**The cost of operation is very low once the nuclear power plant is commissioned. The costs in operation are only the payment of workers to run the plant and the cost of the raw materials required.

Disadvantages

- **Higher Risk of Radiation Exposure:**The radiation emitted during the fission reaction is extremely harmful to humans and animals. The workers who are exposed while working at nuclear power plants are at great risk radiation poisoning, cancer and other diseases associated with radiation.
- **Highly Vulnerability:**High vulnerability is a potential risk that is involved in nuclear power plants. The enormous energy produced in a fission reaction can be utilized to create nuclear weapons. Any small accident at a nuclear plant can cause huge damage, affecting the lives of millions.
- **Radioactive Contamination Risk:**The waste that is released from the nuclear power plant is highly radioactive and harmful for all living beings. There are high chances of water contamination from these plants which can cause serious diseases and death in living beings.
- **High Cost Of Plant Commissioning:**To build a nuclear power plant requires a huge investment, and this is due to the latest technologies and safety measures that are required to run it properly.

6.8 RADIOACTIVITY

Due to nuclear instability, an atom's nucleus exhibits the phenomenon of Radioactivity. Energy is lost due to radiation that is emitted out of the unstable nucleus of an atom. Two forces, namely the force of repulsion that is electrostatic and the powerful forces of attraction of the nucleus keep the nucleus together. These two forces are considered extremely strong in the natural environment. The chance of encountering instability increases as the size of the nucleus increases because the mass of the nucleus becomes a lot when concentrated. That's the reason why atoms of Plutonium, Uranium are extremely unstable and undergo the phenomenon of radioactivity.

Some Important Terms Related To Reactor

CHAIN REACTION:it refers to a process where neutrons released in fission produce an additional fission in at least one further nucleus. Then the nucleus in turn produces neutrons, and this process goes on repeating itself. The process may be controlled (nuclear power) or uncontrolled (nuclear weapons).

CONTROLLING RODS: DescriptionControl rods are used in nuclear reactors to control the fission rate of uranium or plutonium.these rods are generally composed of chemical elements such as boron, cadmium, silver, or indium, that are capable of absorbing many neutrons without themselves fissioning

MODERATOR: These are used in a Nuclear Reactor to regulate the speed of fast moving neutrons. Generally light water is used as a neutron moderator. Other alternatives include beryllium, graphite ,heavy water .

TYPES OF NUCLEAR REACTORS

BOILING WATER REACTOR

These are a type of light water nuclear reactor usually used for the generation of electrical power. After the PRESSURISED WATER REACTORS(a type of nuclear water reactor) ,It is the second most common type of electricity-generating nuclear reactor. A boiling water reactor (BWR) uses demineralized water as a coolant and neutron moderator. Heat is produced by nuclear fission in the reactor core.

PRESSURIZED WATER REACTORS

The core inside the reactor vessel creates heat.
Pressurized water in the primary coolant loop carries the heat to the steam generator.
Inside the steam generator, heat from the primary coolant loop vaporizes the water in a secondary loop, producing steam.
The steamline directs the steam to the main turbine, causing it to turn the turbine generator, which produces electricity.
The unused steam is exhausted to the condenser, where it is condensed into water. The

resulting water is pumped out of the condenser with a series of pumps, reheated, and pumped back to the steam generator. The reactor's core contains fuel assemblies that are cooled by water circulated using electrically powered pumps. These pumps and other operating systems in the plant receive their power from the electrical grid. If offsite power is lost, emergency cooling water is supplied by other pumps, which can be powered by onsite diesel generators. Other safety systems, such as the containment cooling system, also need electric power. PWRs contain between 150-200 fuel assemblies.

PRESSURISED HEAVY WATER REACTORS

It is a nuclear power reactor,which generally uses unenriched natural uranium as its fuel, that uses heavy water (deuterium oxide D2O) as its coolant and moderator. The coolant ,that is;the heavy water, is kept under pressure, allowing it to be heated to higher temperatures without boiling, much as in a typical pressurized water reactor.although heavy water is quite expensive than ordinary light water, it yields greatly enhanced neutron economy, allowing the reactor to operate without fuel enrichment facilities (mitigating the additional capital cost of the heavy water) and generally increasing the ability of the reactor to efficiently make use of alternate fuel cycles.

ADVANCED HEAVY WATER REACTORS

It is a kind of latest invention and design for the next generation. The advanced heavy-water reactor (AHWR) burns thorium in its fuel core. The AHWR will form the third stage in India's three-stage fuel-cycle plan. It is a thorium fuel based vertical pressure tube type, heavy water moderated and boiling light water cooled reactor. This AHWR having 300 MWe capacity is designed by BARC and is intended to serve as a technology demonstrator for a range of technologies for Thorium utilisation as well as for a number of enhanced safety features that have been incorporated.

RESEARCH AND DEVELOPMENT IN INDIA

The Department of Atomic Energy is involved in the research and development activities related to nuclear technology through its five organisations. Moreover, it also gives financial assistance to allied Institutes and also promotes research activities in academies and universities.

Bhabha Atomic Research Centre (BARC)

The Bhabha Atomic Research Centre (BARC) is the premier nuclear research facility of India, it is headquartered in Trombay(Mumbai) Maharashtra. The centre comprises a number of multi-disciplinary research facilities with extensive infrastructure for advanced research and development that covers the entire range of areas related to nuclear science, engineering and related areas.

The core mandate of BARC is to sustain peaceful applications of nuclear energy, primarily for power generation. It manages all facts of nuclear power generation, from theoretical design of reactors to, computerised modelling and simulation, risk analysis, development and testing of new reactor fuel materials, etc. BARC is also involved in research areas related to spent fuel processing and safe disposal of nuclear waste. Also, other research focus areas are applications for isotopes in industries, medicine, agriculture, etc.

Indira Gandhi Centre for Atomic Research, Kalpakkam (IGCAR)

This centre for atomic research is the second largest establishment of the Department of Atomic Energy after the Bhabha Atomic Research Centre. IGCAR was established at Kalpakkam, 80 KMs south of Chennai [MADRAS], in 1971 with the main goal of performing broad based multidisciplinary programme of scientific research and advanced Engineering, focussed on the development of sodium cooled Fast Breeder Reactor [FBR] technology, in India. ThisFBR forms the part of the second stage of Indian Atomic Energy Programme, which aims at exploring the potential of the country for utilization of the extensive Thorium reserves and providing means to meet the large demands of electrical energy in the 21st century.

In this light, a modest beginning was made by constructing a sodium cooled Fast Breeder Test Reactor [FBTR], with a minimal power of 40 Mwt. The FBTR achieved its first criticality on 18th Oct, 1985 and since then it has been working at its maximum attainable power level of 10.5 MWt with a small core. It is one of the first reactors in the world to use Plutonium Uranium mixed carbide as a driver fuel.

Over these years, theIGCAR has established a large number of research and development facilities covering the entire spectrum of FBR technology related to Sodium Technology, Reactor Engineering, Reactor Physics, Metallurgy and Materials, Chemistry of Fuels and its materials, Fuel Reprocessing, Reactor Safety, Control and Instrumentation, Computer Applications etc., and a strong base has been developed in a variety of disciplines related to this advanced technology.

The experience and expertise gained after the successful operation of FBTR, the Centre has moved towards the design and construction of 500 MWe, Prototype Fast Breeder Reactor

[PFBR]. Various research activities in the fields like Structural Mechanics, sodium-water, thermal Hydraulics and flow induced vibration, Component Testing in high temperature sodium environment, reaction, hydraulic development of sodium pumps etc., were pursued and the design was completed. The PFBR is under advanced stage of construction and commissioning by BHAVINI.

As a part of efforts for closing the fuel cycle, a Fast Reactor Fuel Reprocessing Plant is under construction.A 30 KWt, U233 fuelled mini reactor [KAMINI] has been made operational for neutron radiography, neutron activation analysis etc.,

IGCAR utilizes its expertise and resources in enhancing its standing as a leading Centre of research in various branches of basic, applied and engineering sciences that have a bearing on Nuclear Technology like Structural Mechanics, Heat and Mass Transfer, Material Science, Fabrication Processes, Non-Destructive Testing, Chemical sensors, High temperature thermodynamics, Radiation Physics, Computer science etc.,

The IGCAR not only works in fields of nuclear technology,but also has credentials as a leader of research in various frontier and topical subjects like Quasicrystals, SQUID fabrication programs, exopolymers and experimental simulation of condensed matter using colloidsOxide superconductors, Nano-structures, clusters, etc.,

The expertise and facilities of IGCAR has been utilised into other vital sectors such as Defence, Space and other industries of India in order to develop techniques for reliable solutions to specialized problems.the centre has also collaborated with educational and R & D institutes like Indian Institutes of Technology, Indian Institute of Science, Pilani, Regional Engineering Colleges, National Research Laboratories, Public Units and Institutes abroad.

Centre For Advanced Technology (Indore)

The Raja Ramanna Centre for Advanced Technology is a unit of Department of Atomic Energy, Government of India, engaged in R&D in non-nuclear front-line research areas of lasers, particle accelerators and related technologies.

Variable Energy Cyclotron Centre

It is a research and development unit of the Department of Atomic Energy. The centre is located in Kolkata, and involved in performance of research in basic and applied nuclear sciences along with development of the latest nuclear particle accelerators. It has a collaboration with the CERN (EUROPE).

Atomic Minerals Directorate

The Directorate, mainly involved in policy and programmes related to Exploration and Research, is the oldest unit of the Department of Atomic Energy (DAE). AMD was created on July 29, 1949 as ‘Rare Minerals Survey Unit’ headquartered in New Delhi, Under the Atomic Energy Act, passed by the Govt. of India on April 15, 1948 and which was followed by the creation of the Atomic Energy Commission (AEC) in 1948. In the beginning it was named as ‘Raw Materials Division’ and then later on called ‘Atomic Minerals Division’ in 1958. The headquarters of AMD were later shifted to Hyderabad in1974.

In keeping with its growing stature as one of the country’s leading scientific organizations involved in multi-disciplinary and multi-faceted exploration-cum-analytical-cum research activities, the ‘Division’ was rechristened as a ‘Directorate’ on July 29, 1998 on the eve of its stepping into the ‘Golden Jubilee’ Year.

The operations of AMD started on October 3, 1950 with a nucleus of 17 Geoscientists which has grown to 2354 personnel by 2016. The principal mandate of the unit was to carry out geological exploration and discover mineral deposits required for the Atomic Energy power program of the country.

6.9 MISCELLANEOUS

ISOTOPES:

- It is defined as variants of a particular element where these variants will have the **same number of protons but differ in the number of neutrons in the atom.**

- Due to the unequal numbers of neutrons, the isotopes of elements usually have a **different mass.**
- Generally, elements which have odd atomic numbers will have one or two stable isotopes whereas elements with even atomic numbers will mostly have three or more stable isotopes. However, there are also exceptions like carbon, helium, and beryllium.
- An isotope is usually denoted or identified by the name of the particular element at the beginning, which is followed by a hyphen and the mass number.
- Some common examples that can be cited are the isotopes of hydrogen and carbon. Talking about the element Hydrogen, it has three stable isotopes, namely protium, deuterium, and tritium.
- These isotopes have the same number of protons, but a different number of neutrons wherein protium has zero, deuterium has one and tritium has two.
- Looking at carbon, it also has three isotopes, namely Carbon-12, Carbon-13, and Carbon-14. The numbers 12, 13, and 14 are the isotopes' atomic masses. It is to be noted that Carbon-12 is a stable isotope whereas carbon-14 is usually a radioactive isotope.
- Apart from the above-mentioned elements, some other common isotope examples include – Zinc has 21 known isotopes, Tin has 22 isotopes, Neon is a mix of 3 isotopes, natural xenon consists of a mixture of 9 stable isotopes, Nickel has 14 known isotopes.

6.10 RADIOISOTOPES:

- These are radioactive isotopes of an element which can also be defined as atoms that contain an unstable combination of neutrons and protons or having excessive energy in their nucleus.
- Different isotopes of the same element have the same number of protons in their atomic nuclei but differing numbers of neutrons.
- The unstable nucleus of a radioisotope can occur naturally, or as a result of artificially altering the atom. In some cases, a nuclear reactor is used to produce radioisotopes, in others, a cyclotron.
- Nuclear reactors are best-suited to producing neutron-rich radioisotopes, such as molybdenum-99, while cyclotrons are best-suited to producing proton-rich radioisotopes, such as fluorine-18.

One of the most common examples of a naturally-occurring radioisotope is uranium.

Applications Of Radioisotope:

Geological dating: in this radioisotopes are used to determine the age of rocks and minerals.

- Carbon dating: is used to determine the age of archaeological objects such as fossils. By knowing the concentration of C-14
- Agriculture: P-32 is used to study the transportation of minerals and salts,killing pests, causing genetic mutations to produce better strains
- Medical treatment: Co 60 is used for cancerous tumours, I-131 used for detection of the thyroid, Na-24 used to detect problems in blood circulation.

NUCLEAR AGRICULTURE:

Some of the most innovative ways being used to improve agricultural practices involve nuclear technology. Nuclear applications in agriculture rely on the use of isotopes and radiation techniques to combat pests and diseases, increase crop production, protect land and water resources, ensure food safety and authenticity, and increase livestock production.

FAO and the International Atomic Energy Agency (IAEA) have been expanding knowledge and enhancing capacity in this area for over 50 years. And the results have led to some major success stories around the world.

Applications in Agriculture:

Animal productivity and Health	The technologies related to nuclear and its components have made a difference in improving livestock productivity, controlling and preventing animal diseases and protecting the environment.
Improved soil and Water Health	In order to maintain healthy soil and water systems, a number of countries are utilizing nuclear technology, which is paramount in ensuring food security for the growing global population.

Pest Management	The nuclear-derived sterile insect technique (SIT) involves mass-rearing and sterilizing male insects before releasing them over pest-infested areas. This novel technology suppresses and gradually eliminates already established pests and also helps in the prevention of the introduction of invasive species – it is also touted to be safer for the environment and human health than conventional pesticides.
Food Safety	To facilitate the trade of safe food and to combat food fraud, Food safety and quality control systems need to be robust at the national level, which costs the food industry up to USD 15 billion annually. Use of Nuclear technology has been helping national authorities in over 50 countries to improve food safety by tackling the problem of harmful residues and contaminants in food products and to improve their traceability systems with stable isotope analysis.
Emergency Response	Radioactivity is present in everything that surrounds us – from the sun to soil. But should a nuclear incident or emergency happen, an understanding of the movement of radioactivity through the environment becomes crucial to prevent or alleviate the impact on agricultural products.
Climate change Adaptation	The agricultural sector uses nuclear and related technologies to adapt to climate change by increasing resource-use efficiency and productivity in a sustainable way.
Seasonal Famine Prevention	Crop-breeding programmes use nuclear technology to help vulnerable countries ensure food security, adapt to climate change and even to tackle seasonal famine.

RADIOCARBON DATING

Carbon dating is one of archaeology's mainstream methods for dating organic objects up to 50,000 years old. This method is based on the idea of radiative decay of Carbon-14 isotopes over thousands of years. Through physics, scientists have discovered that radioactive molecules decay at a specific rate dependent on the atomic number and mass of the decaying atoms. This constant can be used to determine the approximate age of the decaying material through the ratio of radioactive isotopes to the estimated initial concentration of these isotopes at the time of the organism's death. Scientists have concluded that very little change has occurred in the ratio of Carbon-12 to Carbon-14 isotopes in the atmosphere, meaning that the relationship between these two should be very similar to how they remain today.

Without radiocarbon dating, "we would still be foundering in a sea of impressions sometimes bred of inspired guesswork, but more often of imaginative speculation". Carbon-14 dating is a revolutionary advancement in the study of the history of our planet. It is, in fact, leading to the "reconstruction of the history of the world". This method of dating allows researchers to learn about past civilizations, changes in the earth, and in the climate.

Different civilizations and religions have different methods of dating. However, carbon-14 dating offers something particularly valuable, called absolute dating, which is the age of the substance before the current time. This means that it may be used and compared to dates anywhere in the world. In fact, it is considered the, "most important development in absolute dating in archaeology and remains the main tool for dating the past 50,000 years". With this tool, scientists hope to unravel the mysteries of how man developed, when the first man lived, where he went, and create a type of timetable of human life.

Carbon has unique properties that are essential for life on earth. Familiar to us as the black substance in charred wood, as diamonds, and the graphite in "lead" pencils, carbon comes in several forms or isotopes. One less abundant form of carbon has atoms that are 14 times as heavy as hydrogen atoms: carbon-14, or 14C, or radiocarbon.

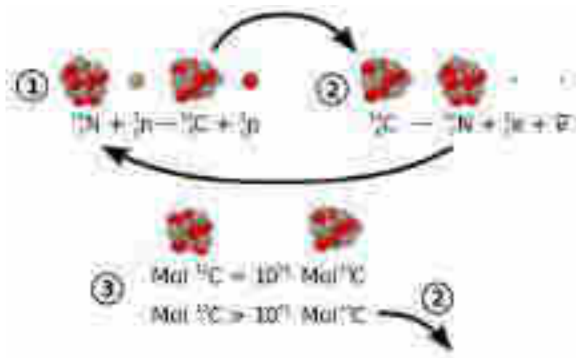


Fig 6.10 :Radiocarbon Dating

Carbon-14 is a radioactive substance. At any given moment carbon-14 is decaying in an object, and if that object is living, it is also being replaced at a steady rate. Carbon- 14 is created when a neutron is excited by a cosmic ray, and then that neutron collides with a nitrogen atom. The carbon isotope is when absorbed by plants through photosynthesis and consumed by animals. Due to the way the sunlight reacts with the atmosphere, it is also taken in by respiration.

RADIOACTIVITY AND FOOD PRESERVATION:

For the preservation of certain foods, the effects of radiation on cells of living or vegetable matter are used, which are effective in destroying microorganisms and parasites

The action of gamma rays radiation, emitted for instance by a cobalt-60 source, leads to ruptures of chemical bonds in their interaction with the matter of living organisms. This process helps in an efficient and reliable elimination of bacteria, fungi and parasites in food. The radioactive treatments are generally more effective since the penetrating power of gamma rays ensures that all points of the product are actually processed.

However, the efficacy are dose dependent. The doses used for preservation and sterilization are adapted to their purpose. The scale of these doses is of course not the same as those applied to humans. For example, we take as low a dose of 50 to 100 grays (Gy), whereas such a dose is considered high in the case of radiotherapy of a cancer and it could be dangerous or harmful if applied non-locally to the whole body.

The low dose irradiation inhibits germination, contributes to deworming of grain and fruit and slows down physiological processes of decomposition. Potatoes, onions, shallots are irradiated to inhibit germination so they are conserved longer. In order to slow down the maturity, the Strawberries and tomatoes get the same treatment. Spices and dried vegetables are also treated to destroy microorganisms.

At moderate dose, we get an extension in time of food preservation by irradiation at medium dose and at higher dose industrial sterilization of meat, spices, and foods prepared by irradiation.

Rays leave no radioactive residues in the product. If they disrupt atoms and molecules, they do not attack the nucleus. Radiation is just energy that passes through food, destroying bacteria and other microorganisms, and then dissipates. The only residue is a small amount of molecules that have been affected in the food by the passage of energy.

INDIA'S NUCLEAR TEST

Operation Smiling Buddha was the codename assigned for India's first successful nuclear bomb test which was carried out on 18 May 1974. The 15-kiloton plutonium device was caused to explode on the army base, Pokhran Test Range, in Rajasthan by the Indian Army under the supervision of several renowned army officials. The yield of the device is believed to be around 8-12 Kilotons of TNT.

India conducted its first successful test of a nuclear bomb on 18 May 1974 at Pokhran. The secret operation was called "Smiling Buddha" and the current MEA nomenclature for the exercise is Pokhran-I.

CONTROLLED THERMONUCLEAR FUSION

The thermonuclear reaction is the fusion of two light atomic nuclei into a single heavier nucleus by a collision of the two interacting particles with high temperature as a consequence of which a large amount of energy is released. Thermonuclear fusion refers to nuclear fusion reactions which take place at extremely high temperatures (example: reactions in the sun). The energy produced here is extremely high but such reactions cannot be controlled. If we are able to achieve conditions where such a reaction can take place while controlling its rate, then we can achieve what is called the controlled thermonuclear fusion.

In an uncontrolled state, these types of reactions give rise to destructive forces. The hydrogen bomb is an example of an uncontrolled fusion reaction. Another differentiating factor between controlled and uncontrolled fusion reactions is that, since conditions are unpredictable in an uncontrolled reaction, they can't be tapped for any use.

Another issue to consider in a controlled thermonuclear reaction is about containing it.The temperature of the hot plasma is so high that it cannot be in contact with any material.

NEUTRON BOMB

This type of bomb is generally an enhanced radiation weapon (ERW),which is a low yield Thermonuclear weapon and is designed for maximization of lethal Neutron Radiation in the immediate vicinity of the blast while the physical power of the blast is minimised

INTERNATIONAL THERMONUCLEAR EXPERIMENTAL REACTOR (ITER)

- Nicknamed as 'miniature sun', ITER is the largest plasma based fusion reactor ever built.
- It is the costliest technological project of the 21st century with an estimated construction cost of $25 Billion.
- The project site is located in Cadarache, Southern France.
- The term 'Thermonuclear' indicates the nuclear fusion reaction.
- ITER will be two times the size of the largest fusion reactor present and the chamber volume will be 10 times the present one.

Timeline of ITER Project

- 1988: The Project was initiated and conceptual design studies ran between 1988-90
- 2005: India joined the project as one of the 7 major partners.
- 2013: Construction of the ITER Tokamak Complex was started.
- 2019: 66% of the construction has been completed.
- 2025: Commissioning and initiation of plasma experiments is expected.

International Collaboration in the Project

- ITER is a collaborative project of thousands of scientists and engineers from 35 countries.
- There are seven major partners; India, U.S.A, E.U, Russia, China, Japan, and South Korea.
- These 7 partners constitute about 50% of the world population and about 85% of world GDP.
- EU alone will bear 45% of the estimated construction cost of $25 Billion while the other 6 countries will contribute 9% each.
- Further, specific tasks and components are assigned to each country.

India's Contributions to ITER

- 17500 Cr. has already been committed by India, amounting to almost 10% of the overall cost of construction, operation and decommissioning.
- India has also provided a Cryostat, the world's largest refrigerator, weighing around 3800 tons and made with stainless steel.
- It will cover the entire structure and keep the magnetic components at a very low temperature (less than -200OC) for maintaining the superconductivity of magnets.
- It was built by L&T Ltd. in Gujarat.
- India is also assigned with the development of critical components such as:
    - Cooling water
    - Vessel in-wall shielding blocks.
    - Radio frequency heating source.
    - Diagnostic neutral beam system, etc.
    - The Institute of Plasma Research (IPR) at Ahmedabad will oversee the technological commitments of India.
    - Around 100 Indian scientists are also involved in the project.
    - Prime Minister Narendra Modi recently visited the project site and also held discussions with French President Emmanuel Macron.

Benefits to India from ITER:

Being a major partner in the project, would help India to accelerate towards the goal of building a fusion reactor, much earlier than the original deadline of 2035. Moreover, working on the project would be an enriching experience for our scientific community as well as industry.

Having become a full partner, India will be involved in the manufacturing of key components like cryostat vessels, cryogenic lines and distribution systems. Since these components will be manufactured in India using cutting -edge technology, it would be a great experience for both the manufacturers as well as the research programmes for our own national fusion projects.

Results of the experiments and Intellectual Property Rights generated during it will be shared with all the partner countries, including India, which will benefit its regime. Along with it, in the long run, the project would facilitate development and growth of Fusion technology In India which will be effective in meeting the energy demand of the Country besides being a clean source. Thus, not only will it reduce dependency on fossil fuels but will also cater to India's quest for SUSTAINABLE DEVELOPMENT.

INDIA’S NUCLEAR DOCTRINE

The Nuclear Doctrine of India is based on the principle that India will only use a nuclear weapon in retaliation to a country’s attempt of attacking India, its states or its army with a nuclear weapon. Nuclear Doctrine, in general, is how a country with a nuclear weapon uses the weapon in peace and at the time of war.

The Nuclear Doctrine of India is based on three main pillars. The three pillars of India’s nuclear doctrine are as follows:

- No first use
- Credible minimum deterrence
- Civilian control (NCA)

All other components of the doctrine such as survivability strategic(the ability of personnel, equipment, and systems to survive the effects of **nuclear** weapons) trend, punitive retaliation in rapid response and shift from peacetime deployment to fully employable forces in the shortest possible time are all strict mathematical derivations of the above three basic principles.

Indian's nuclear doctrine is the most responsible doctrine which aims at providing the minimum credible deterrent. It is a consensus document and does not restrict the country from exercising its nuclear weapon options in any manner. It offers complete elasticity in deciding the number of nuclear weapons India should possess.

CHAPTER 7: EMERGING TECHNOLOGIES (NANOTECHNOLOGY)

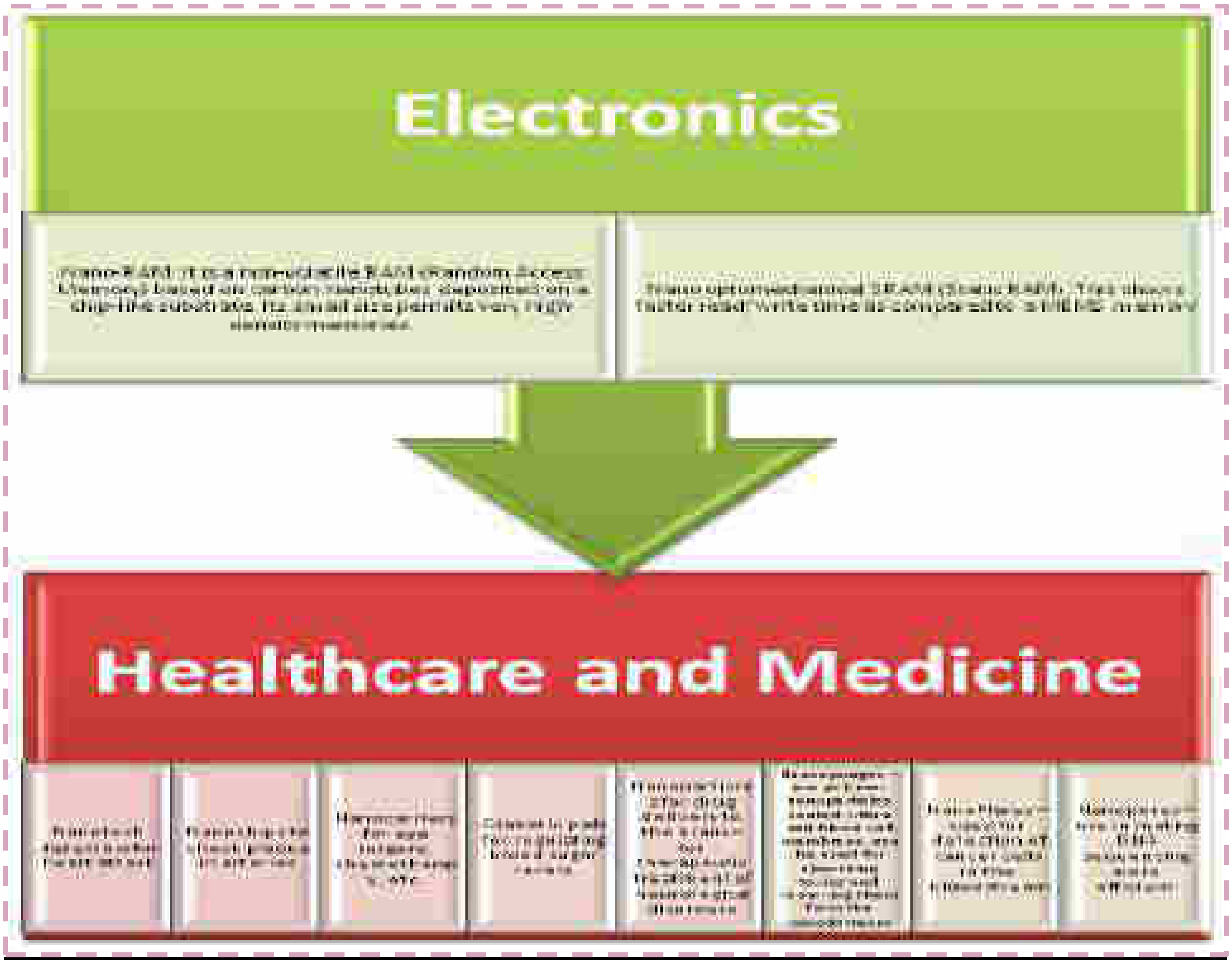
7.1 ORIGIN OF NANOTECHNOLOGY

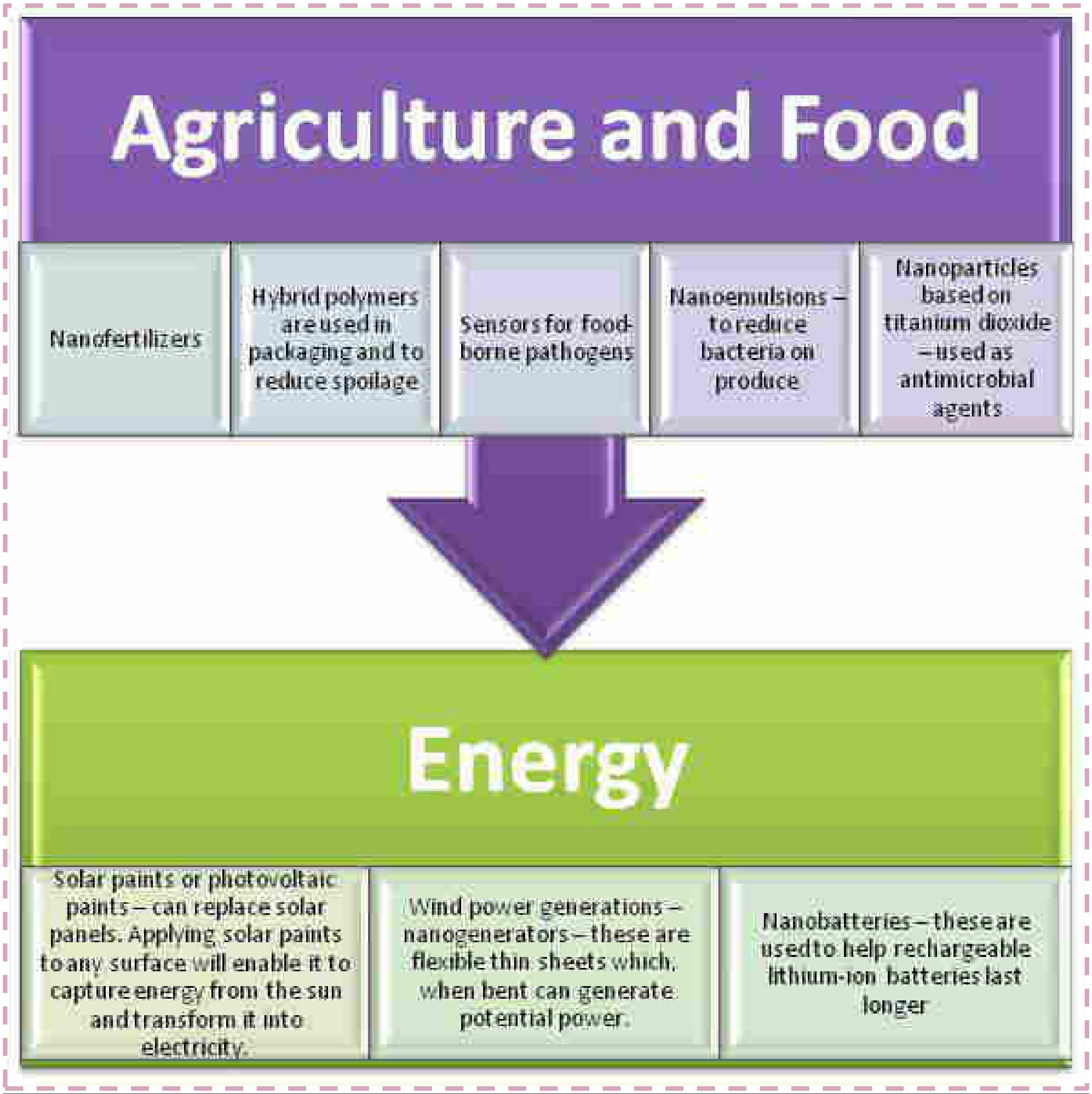
The concept behind the principle of Nanotechnology originated in a talk entitled, “There’s Plenty of Room at the Bottom” by physicist Richard Feynman in 1959. The term nanotechnology was actually coined by Professor Norio Taniguchi. In 1981, the scanning tunnelling microscope was invented, which made it possible to "see" individual atoms. This and the invention of the atomic force microscope (AFM) made it possible for nanotechnology to become a reality.

Definition

Nanotechnology is the technology that involves the manipulation of matter on atomic, molecular and supramolecular scales. This includes particles of a **scale 1 to 100 nanometers.**

7.2 APPLICATIONS OF NANOTECHNOLOGY





Agriculture and Food
Nanofertilizers
Hybrid polymers are used in packaging and to reduce spoilage
Sensors for food-borne pathogens
Nanoemulsions – to reduce bacteria on produce
Nanoparticles based on titanium dioxide – used as antimicrobial agents
Energy
Solar paints or photovoltaic paints – can replace solar panels. Applying solar paints to any surface will enable it to capture energy from the sun and transform it into electricity.
Wind power generations – nanogenerators – these are flexible thin sheets which, when bent can generate potential power.
Nanobatteries – these are used to help rechargeable lithium-ion batteries last longer

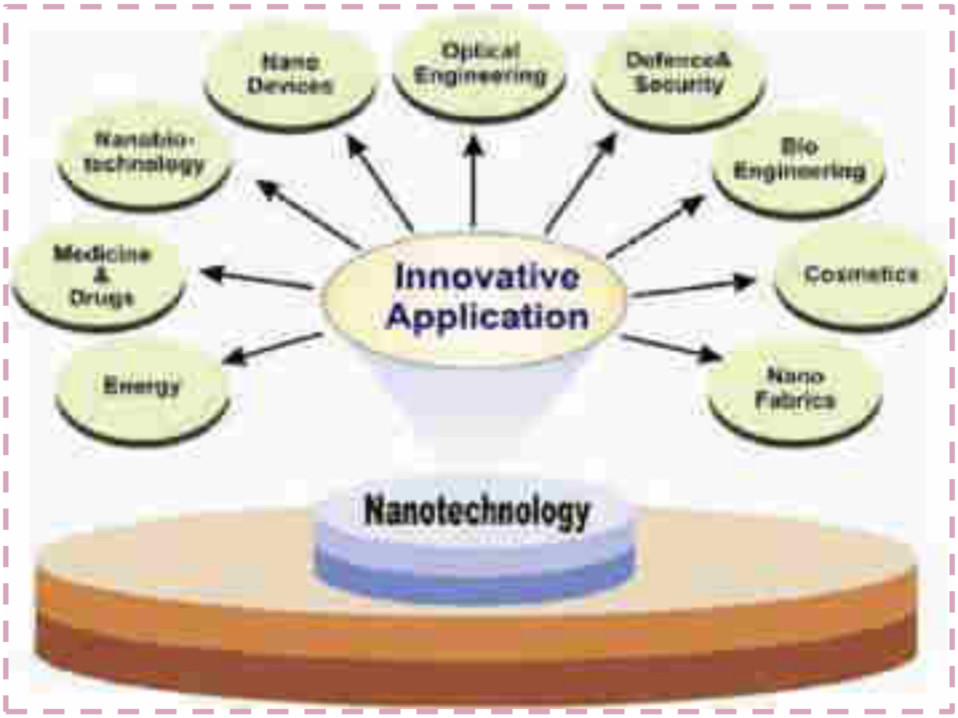


Image: Innovative Applications Of Nanotechnology

Source: Researchgate

7.3 INITIATIVE TAKEN BY THE GOVERNMENT OF INDIA

1. **Nano Science Technology Initiative (NSTI)**

In 2001, the Department of Science and Technology launched the Nano Science and Technology Initiative (NSTI) in order to focus on R&D in Nano-Science and Nanotechnology. The programme supports R&D projects, strengthening of characterization and infrastructural facilities, creation of a centre of excellence, generation of trained manpower, joint projects between educational institutions and industry for application development, etc.

2. **Nano Mission**

The Government of India launched the Nano Mission in 2007 under the Department of Science and Technology. Its objectives:

- Basic Promotion of Nanotechnology
- Infrastructure Development
- Establishment of R&D in Nanoscience Applications

- Establishment of Development Centre for Nanosciences
- Human Development in Nanotechnology
- International Collaborations

India has been able to **rank amongst the top 5 countries in the world** for Scientific Publications in Nanoscience & Technology due to the efforts led by the Nano Mission.

The Nano Mission has established national dialogues to promote R&D in the development of standards for nanotechnology and for laying down a **National Regulatory Framework Road-Map for Nanotechnology** (NRFR-Nanotech).

3. COVID-19 Nano Coating

The Department of Science and Technology and the Science and Engineering Research Board (SERB) called for a Short-term Research Grant for Nano Coating COVID-19 in April 2020.

This rapid project was necessary for the emerging health care requirements in order to combat the COVID-19 Pandemic. The goals of the project are to focus on the following areas:

- **Antiviral Nano-coatings:** It will be coated/used on the appropriate material for producing anti-COVID-19 Triple Layer Medical masks and N-95 respirator or better masks in large quantities.
- All components of Personal Protective Equipment (PPE).

4. ICONSAT 2020

The International Conference on NanoScience and NanoTechnology (ICONSAT) is a series of biennial international conferences held in India under the aegis of the Nano Mission, Department of Science and Technology (DST).

ICONSAT 2020 was organized during 5th-7th March at Kolkata (West Bengal).

Objectives of ICONSAT

- Bringing out Cutting Edge Nano Technology for the development of Physics, Chemistry and Material domains.

- **Integration of 5Ms – Mechanical, Material, Machines, Manufacturing and Manpower with the help of NanoScience and NT.**
- Integration of NT with Sustainable Development.
- Emphasizing the need to create a network of experts in nanoscience and to collaborate the knowledge across sectors like energy, agriculture, transport, health and so on.
- Providing a potential platform for young researchers and students from within the country and abroad to keep pace with the latest development in the emerging areas of Nano Science and Technology.

Indian Nanoelectronics Users Programme (INUP) initiated by Ministry of Electronics and Information Technology (MeitY) is being implemented at Centre of Excellence in Nanoelectronics (CEN) at IISc and IIT Bombay and has provided a great opportunity for R&D community all over the country for accessing a state of the art nanofabrication facilities for undertaking research and skill development in Nanoelectronics.

7.4 BLACK GOLD DEVELOPED BY INDIAN SCIENTIST

Scientists at Tata Institute of Fundamental Research (TIFR) used gold nanoparticles and by rearranging size and gaps between them developed a new material, which has unique properties such as capacity to absorb light and carbon dioxide. Gold does not have these properties, therefore 'black gold' is being called a new material. In appearance it is black, hence the name 'black gold.'

The Scientists believe that it can be potentially used for **applications** ranging from solar energy harvesting to desalinating seawater. One of the most fascinating properties of the new material is its **ability to absorb the entire visible and near-infrared region of solar light.** It does so because of inter-particle plasmonic coupling as well as heterogeneity in nanoparticle size. Black gold could also act as a catalyst and could **convert carbon dioxide into methane at atmospheric pressure and temperature using solar energy**

7.5 CONCERNS RELATED TO NANOTECHNOLOGY

- India spends only a fraction of the amount spent by countries such as the USA, China, Japan, etc. on nanotechnology.

- The quality of research needs to be improved significantly. Only 16% of the papers from India figured in the top 1% publications in 2011.
- Only 0.2% of the patents filed in the US Patent Office is from India in this field.
- Although the target number of PhDs in nanotechnology is 10000 per year by the Ministry of HRD, the current number is just 150 per annum.
- The contribution of the private sector is minimal in this domain.

Scope for potential

- A team from IIT Madras used nanotechnology to decontaminate arsenic from water.
- A team from IIT Delhi has engineered a self-cleaning technology to be used in the textile industry.

7.6 AUGMENTED REALITY

Definition

Augmented Reality (AR) is the technology which superimposes an image onto a user's view of the real world and enhances it with sound, touch, and even smell. It is a combination of the real scene viewed by the user and a virtual scene generated by the computer. AR is a technology which is going to blur the lines of reality.

Augmented Reality has moved beyond headsets and gaming and permeated into numerous industries. It is increasingly being adopted for a variety of uses like assembly, maintenance, repair, education, training, retail showcasing and diagnostics.

AR makes workers more efficient by providing them with an additional layer of knowledge and insights. Augmented Reality remote assistance can improve training in situations where new hires need assistance. This tech enables real-time collaboration between field personnel and remote experts.

Applications

Defence	**Health**
It helps in improving the situational awareness of the soldiers using AR technology. The tech is named as Tactical Augmented Reality (TAR). This tech has an eyepiece that assists soldiers on the battlefield to precisely locate their positions in addition to the location of others (friends and enemy soldiers).	Traditionally handheld ultrasound scanners are used in reconstruction surgery for locating blood vessels, and bones. However, AR technology has the potential to replace ultrasound scanners as it will help in locating the blood vessels very accurately and in a shorter time span.
Pharmaceuticals	**Logistics**
Augmented Reality tools can help scientists to picture the structure of complex molecules. Drug developers usually work with static models. The AR will help the developers to step inside the molecule and see how it moves and responds to different stimuli and situations. This will reduce errors and reduce the years-long drug development cycle.	AR will benefit logistics industries at multiple levels of their operations. • Optimizing warehouse operations • Optimizing transportation • Last-mile delivery • Enhanced value-added services
Advertisement	**Miscellaneous**

For example, Jaguar Land Rover put prospective car buyers in the virtual driver’s seat of its latest models without making the visit to the dealership. Consumers could launch the AR capability directly from a banner ad without any need to install an app. Customers can see the outside view seated at the driving seat through transparent windows.	● Various filters on Snapchat and Instagram are an example of Augmented Reality. ● Scanning your QR code using your phone’s camera provides additional information on the screen. ● Google Glass and other Head-up Displays (HUD) put Augmented Reality directly into the glasses. These glasses could be used as reminders for patients undergoing medication. ● Retail companies use it to help customers envisage aesthetics when new furniture is placed to redesign the interiors of their homes. ● Gaming – Pokemon is one of the most famous games to hit a big chord with the public. ● AR is used in the field of language translation. ● Law enforcement agencies can use AR tech to recognize criminals in huge crowds. ● If a car breaks down, people can fix their cars using AR tech, repair and maintenance can be carried out without the help of mechanics. This tech will recognize the vehicle parts via object recognition, describe and

	picture all required repair and maintenance steps in detail and real-time, along with information about any equipment requirements.

7.7 RECENT DEVELOPMENTS IN INDIA

The government launched an Augmented Reality application named 'Sakaar':

- Sakaar **consists of 3D models of MOM, RISAT, rockets (PSLV, GSLV Mk-III);** videos of INSAT 3D-predicting cyclones, GSLV D5/Cryo, Mars Orbiter Mission (MOM) orbit insertion, launch video of MOM, 360 degrees animated view of MOM; Anaglyph of Mars surface.

First Augmented Reality Centre in India:

- For education and training institute, to be set up in Varanasi.
- It will be established in a tie-up with Eon Reality.

CHAPTER 8: PHENOMENA OF NATURAL SCIENCE

Science encompasses the systematic study of the structure and behaviour of the physical and natural world through observation and experiment, and technology is the application of scientific knowledge for practical purposes. Science goes with conquering new frontiers of nature and technology enables the speedy growth of it. Science demystifies magic and miracles and provides satisfactory answers to human quest. Controlled methods are generally used in the discovery of science. Science also goes with fathomless human imagination and establishes truth for common observation. Universalism, objectivity, skepticism and organised criticism are the rare impulses used in the progress of science and scientific temperament. The technological apparatus has enabled humans to make many breakthroughs. The domain of science and technology can easily be comprehended through physics, chemistry and biology. Technology emerges as powerful tools to accelerate the momentum of scientific progress. The tripartite of physical observation of nature, the chemical actions and reactions and human and plant anatomy have immense power to control deterministically the living and non-living beings. Any average mind person is expected to have a clear hold on it.

BIOLOGY

Aristotle is known as the father of Biology. He widely studied the natural world and examined its origins using scientific insights and systematic observations rather than connecting it to divine interference. Aristotle's biology theory outlines five major biological processes: temperature, metabolism, regulation, inheritance, embryogenesis and information processing. He was also the first to uncover the relationship between animals and establish a system of classification.

8.1 INTEGUMENTARY SYSTEM

The integumentary system is the organ system that protects our body from any form of damage that includes skin, hair, scales and nails. It works as waterproofing, cushion and protection to deeper tissues. It excretes waste and regulates temperature of our body. Integumentary system is an attachment site for sensory receptors to detect pain, sensation, pressure and temperature and vitamin D synthesis.

The skin has three major layers of tissues, viz. epidermis, dermis and hypodermis. The epidermis is a thin, tough, outer layer made up of epithelial cells and it does not contain blood vessels. Stratum corneum is the outermost portion of the epidermis, prevents most bacteria, viruses and other foreign substances from entering the body. Melanocytes produce the pigment melanin, function is to filter out ultraviolet radiation from sunlight. Langerhans cells are part of the skin's immune system which helps detect foreign substances and defend the body against infection.

Dermis is thick layer next to epidermis that is fibrous and elastic that gives the skin its flexibility and strength. It contains nerve endings, sweat glands and oil glands, hair fallacies, and blood vessels. Sweat glands produce sweat in response to heat and stress. The sebaceous glands secrete sebum into hair moist and soft and acts as a barrier against foreign substances. The blood vessels of the dermis provide nutrients to the skin and help regulate body temperature.

Hypodermis' purpose is to attach skin to underlying bone and muscles as well as supplying it with blood vessels and nerves. Fat layer helps insulate the body from heat and cold, provides protective padding and serve as an energy storage area.

8.2 DIGESTIVE SYSTEM

The digestion system includes four important stages, viz. ingestion, digestion, absorption and elimination. The digestive system includes alimentary canal viz. salivary glands, pharynx, esophagus, stomach, small intestine, large intestine, large intestine ending in the rectum and anus and accessory digestive organs. These are liver, gallbladder and pancreas. Food moves from one organ to the next through muscle action called peristalsis. The salivary glands in the mouth produces saliva contains an enzyme amylase that digest the starch from food into smaller molecules. The stomach has three mechanical tasks. To store the swallowed food, to mix up the food, liquid and digestive juice produced by the stomach and to empty its contents slowly into the small intestine. The liver is the largest gland of our body. It secrets bile which helps the body to absorb fat. The pancreas produces enzymes that helps digest proteins, fats and carbohydrates. It also makes a substance that neutralizes stomach acid. Small intestine has 3 divisions such as duodenum, jejunum and ileum. The inner wall of the small intestine is covered with millions of microscopic, finger like projections called villi. The villi are the vehicles through which nutrients can be absorbed into the body. The larger enzyme secrets no enzyme and plays only a minor role in the absorption of nutrients. The three divisions of large intestine are caecum, colon and rectum. The rectum is where feces are stored until they leave the digestion system through the anus as a bowel movement. Disorders and disease of digestive system may primarily cause gastrointestinal infection, caused by virus, by bacteria such as salmonelia, shigellia, compylobactor of E coli. Hepatitis is a condition when liver becomes inflamed and may lose its ability to function.

8.3 RESPIRATORY SYSTEM

The respiratory system is an anatomical system of an organism used for respiration. Mouth, nose and nasal cavity are the visible parts of upper respiratory system. The nostrils act as an air intake, called Cilia that protects the nasal passageways and other parts of the respiratory tract. Pharynx is the part of the digestive system as well as the respiratory system because it carries both food and air. Larynx is also known as the voice box as it is where sound is generated. It also helps protect the trachea by producing a strong cough reflex if any solid objects pass the epiglottis. Trachea that is the wind pipe carries air from the throat into the lungs. The inner membrane of the trachea is covered with cilia. Bronchi is one of the two divided parts of trachea, one entering the left and one entering the right lung. Bronchioles is a tertiary bronchi that continues to divide and become bronchioles, very narrow tubes, less than 1 millimeter in diameter. Alveoli is an individual hollow cavities contained within alveolar sacs. Alveoli has very thin walls which permits the exchange of gases viz. oxygen and carbon dioxide. Thorax or the chest cavities is the airtight box that houses the bronchial tree, lungs, heart and other structures. Diaphragm is located below the lungs. It is a large, dome shaped muscle that contracts rhythmically and continually and most of the time, involuntarily. The tidal volume is the volume of air that is installed or exhaled in a single such breath. Breathing is a constant process where the body constantly breathe in and out of the day. Respiration is also a process of diffusion. In the process oxygen moves from the alveoli to the blood through the capillaries lining the alveolar walls. Blood contains Hemoglobin- a specialized protein that binds to oxygen in the lungs so that oxygen can be transported to the rest of the body. Carbon dioxide which produced during the process of diffusion, moves out of the cells into the capillaries, where most of it is dissolved in the plasma of the blood. As an issue in respiration a chronic inflammatory lung disease may also cause contract in the wind pipe that is also known as asthma. Asthma is triggered by irritants in the air such as cigarette smoke, asthma flares. Smoking has two fold effects on respiration. It may irritate the cells lining and respiratory tract. Long terms effects include disease like emphysema of which the earlier is much common.

8.4 CIRCULATORY SYSTEM

The circulatory system is responsible for the transport of water and dissolved materials throughout the body, including oxygen, carbon dioxide, nutrients and waste. The structure of circulatory system is dependent on heart. The heart has four chambers, viz. right atrium, left atrium, right ventricle and left ventricle. The bottom part of the heart is divided into two chambers called the right and left ventricles which pump blood out of the heart. The upper part of the heart is made up of the other two chambers of the heart, the right and the left atria. Arteries carry blood away from the heart. They are the thickest blood vessels, with molecular walls that contract to keep the blood moving away from the heart and through the body. Two coronary arteries provide oxygen and nourishment to the muscles of the heart. Vein carry blood back to the heart, waste products such as carbon dioxide are also removed by the capillaries. The working of Circulatory system consists of one complete heartbeat makes up a cardiac cycle, which includes two phases viz. the ventricles contract sending blood into the pulmonary and systematic circulation then the ventricles relax and fill with blood from the atria, which makes up the second phase of the cardiac cycle. The normal heart beat is 70-72 per minute in males and 78-82 per minute in females. The heartbeat of a child is more than that of an adult that is 140 heart beat per minute. The senatorial or SA node, a small area of tissue in the wall of the right atrium, sends out an electrical signal to start the contracting of the heart muscle. These electrical impulses cause the atria to contract first, and then travel down to the atrioventricular or AV node. In the systematic circulation, blood travels out of the left ventricle, to the aorta, to every organ and tissue in the body, and then back to the right atrium. In the pulmonary circulation, blood low in oxygen but high in carbon dioxide is pumped out the right ventricle into the pulmonary artery which branches off in two directions. The coronary circulation includes the coronary arteries to supply blood to the heart mussels. The blood transports life supporting food and oxygen to every cell of the body and removes their waste products. Blood has two main constituents. The cells or corpuscles comprise about 45% and the liquid portion, or plasma in which the cells are suspended, comprise 55 %. The blood cells comprise three types: red blood Cells (RBC) or Erythrocytes, White Blood Cells (WBC) or leukocytes and Platelets or thrombocytes. Anemia is a deficiency of hemoglobin in the blood. It can be caused by blood loss abnormal destruction of the red cells, and inadequate red cells formation by the bone marrow. Leukemia is about the excessive increase in abnormal leukocytes that may occur for unknown reasons, resulting in the disease known as the leukemia. Atherosclerosis is a disorder of large and medium sized arteries, such as the large coronary arteries that supply the heart muscles with oxygen. The disorder is characterized by a buildup of fatty deposits, called plaques, on the inner walls of arteries. The most important peripheral vascular disease of the veins is thrombophlebitis or phlebitis. This disorder involves the formation a blood clot in large veins, usually in the leg or pelvis. Hypertension is the high blood pressure that is often secondary to hardening of the arteries. As the arteries lose their elasticity the heart has to beat harder to force the blood through. The result is high blood pressure.

8.5 NERVOUS SYSTEM

The network system is a network of specialized cells called neurons that coordinate the actions and transmit signals between different parts of the body. The central nervous system of vertebrates contains the brain, spinal cord and retina. The peripheral nervous system consists of sensory neurons, clusters of neurons called ganglia and nerves connecting them to each other and to the central envious system. All neurons have three parts: dendrites, axon and sensory. The dendrites receives information from another cell and transmit the message to the cell body. The axon conducts messages away from the cell body. The sensory neurons carry messages from sensory receptors to the central nervous system.

The largest and most complex part of the body is forebrain. It consists of cerebrum. The cerebrum contains the information that essentially makes us who we are, our intelligence, memory, speech, ability to feel etc. The outer layer of the cerebrum is called cortex in the inner part of the forebrain sits the thalamus, hypothalamus and pituitary gland. The thalamus carries messages from the sensory organs like eyes, ears, nose and finger to cortex. The hypothalamus controls the pulse, thirst, appetite, sleep patterns and other processes in our bodies that happen automatically. The midbrain is located underneath the middle of the forebrain that acts as a master coordinator for all the messages going in and out of the brain to the spinal cord. The hindbrain sits underneath the back end of the cerebrum and contains cerebellum, pons and medulla. The brainstorm takes in, sends out and coordinates all of the brains' messages. It also controls many of the body's automatic functions, like breathing, heart rate, blood pressure, swallowing, digestion, and blinking. The sympathetic nervous system prepares the body for sudden stress. The parasympathetic nervous system helps the digestive tract move along so our bodies can efficiently take in nutrients from the food we eat. Disease and Huntington's disease are due to imbalances of neurotransmitters Parkinson's is due to a dopamine deficiency. Alsheimer's disease is associated with protein plaques in the brain. One of the critical problems of nervous system is brain tumors. They usually grow in one place and may be curable through surgery. A malignant tumor is cancerous and more likely to grow rapidly and spread. Meningitis and encephalitis are the infections of the brain and spinal cord that are usually caused by bacteria or viruses. Meningitis is the inflammation of the coverings of the brain and spinal cord and encephalitis is the inflammation of the brain tissue.

8.6 MUSCULAR SYSTEM

Three kinds of muscles are identified in our body viz. Skeletal, Visceral and Cardiac. Muscles is a specialized tissue of mesodermal origin. About 40-50 per cent of the body weight of a human adult is contributed by muscles. Each myofibril has alternate dark and light bands on it. A detailed study of the myofibril has established that the striated appearance is due to the distribution pattern of two important proteins- Actin and Myosin. Utilizing the energy from ATP hydrolysis, the myosin head now binds to the exposed active sites on acitin to form a cross bridge. The myosin release the ADP and Pi goes back to its relaxed state. A new ATP binds and the cross bridge is broken. The ATP is again hydrolyzed by the myosin head and the cycle of cross bridge formation and breakage is repeated causing further sliding. Auto immune disorders affecting neuromuscular junction leading to fatigue, weakening and paralysis of skeletal muscles.

8.7 SKELETAL SYSTEM

Skeletal system consists of a framework of bones and few cartilages. The system has a significant role in movement shown by the body. Bone and cartilage are specialized connective tissues. The axial skeleton comprises 80 bones distributed along the main axis of the body. The skull, vertebral column, strernum and ribs constitute axial skeleton. The skull is composed of two sets of bones-cranial and facial, that totals to 22 bones, Cranial bones are 8 in number. Vertebral column is formed by 26 serially arranged units called vertebrae and is dorsally placed. It extends from the base of the skull and constituents the main framework of the trunk. There are 12 pairs of ribs. Each rib is a thin flat bone connected dorsally to the vertebral column and ventrally to the sternum. It has two articulation surfaces on its dorsal and hence is called bicephalic. Appendicular skeleton is the part of the skeletal system. The bones of the limbs along with their girdles constitute the appendicular skeleton. Each limb is made of 30 bones. The bones of the hand are humerus, radius and ulna, carpals, metacarpals and phalanges. Joints are essential for all types of movements involving the bony parts of the body. Locomotory movements are no exception to this. Joints are points of contact between bones, or between bones and cartilages. Fibrous joints do not allow any movement. This type of joint is shown by the flat skull bones which fuse end-to end with the help of dense fibrous connective tissues in the form of sutures, to form the cranium. Synovial joints are characterized by the presence of a fluid filled synovial cavity between the articulating surfaces of the two bones. Such an arrangement allows considerable movement. Cartilaginous joints are the bones involved in joining bones together with the help of cartilages. Arthritis are inflammation of joints. Osteoporosis is an age related disorder characterized by decreased bone mass and increased chances of fractures. Decreased levels of estrogen is a common cause. Inflammation of joints happen due to accumulation of uric acid crystals.

8.8 ENDOCRINE SYSTEM

The system that controls and coordinates the biochemical produced by body itself is called endocrine system. It mainly consists of two important parts, namely glands and hormones. A gland is a group of cells that produces and secrets, or gives off, chemicals. A gland selects and removes materials from the blood, processes them and secretes the finished chemical product for use somewhere in the body. Exocrine glands, such as the seat and salivary glands, release secretion in the skin or inside of the mouth. Endocrine glands, on the other hand, release more than 20 major hormones directly into the blood stream where they can be transported to cells in other parts of the body. Two important endocrine diseases are diabetes millets (DM1& 2) and Osteoporosis. Diabetes millets (DM) is a group of metabolic disease in which a person has high blood sugar, either because the body does not produce enough insulin or because cells fail to use insulin that is produced. The diabetes can further be classified into two categories, namely Type 1 diabetes and Type 2 diabetes. Type 1 diabetes results from the body's failure to produce insulin and requires person to inject insulin. Type 2 diabetes results from insulin resistance a condition in which cells fail to use insulin properly, sometimes combined with an absolute insulin deficiency. If the body produces too much growth hormone (GH), gigantism or acromegaly (gigantism in adults) can occur, too little growth hormone results a condition called growth hormone deficiency. Osteoporosis is a condition in which bones become fragile and more likely to break. Polycystic ovary syndrome is a condition associated with symptoms of infrequent or irregular menstruation. Thyroid disorder is also produced by the complication in the thyroid gland, influence nearly all of the body's symptoms. Thyroid problems include hyperthyroidism. Cushing's syndrome is produced by cortisol hormone.

8.9 REPRODUCTIVE SYSTEM

The reproductive system of animals can be divided into the internal and external system. Gametes are reproductive cells that unite during sexual reproduction to form a new cell called a zygote. When the haploid male and female gametes unite in the process called fertilization, they form what is called a zygote. In the male, testes produce sperm, and in the female, overies make eggs. Hermaphroditism is one organism has both sexes. Earthworms and garden snails always have both male and female organs. Parthenogenesis is the ability of an unfertilized egg to develop and hatch. There are two major mechanism of fertilization. In external fertilization, used by many aquatic invertebrates, eggs and sperm are simultaneously shed into the water, and the sperm swim through the water to fertilize the egg. In internal fertilization, the eggs are fertilized within the reproductive tract of the female, and then are covered with egg shelf and remain within the body of the female during their development.

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