NEHRU COLLEGE OF ENGINEERING AND RESEARCH CENTRE
(NAAC Accredited)
(Approved by AICTE, Affiliated to APJ Abdul Kalam Technological University, Kerala)

DEPARTMENT OF MECHATRONICS ENGINEERING

COURSE MATERIALS

MR 364 ENERGY ENGINEERING AND MANAGEMENT

VISION OF THE INSTITUTION
To mould true citizens who are millennium leaders and catalysts of change through excellence in education.
MISSION OF THE INSTITUTION
NCERC is committed to transform itself into a center of excellence in Learning and Research in Engineering and Frontier Technology and to impart quality education to mould technically competent citizens with moral integrity, social commitment and ethical values. We intend to facilitate our students to assimilate the latest technological know-how and to imbibe discipline, culture and spiritually, and to mould them in to technological giants, dedicated research scientists and intellectual leaders of the country who can spread the beams of light and happiness among the poor and the underprivileged.

ABOUT DEPARTMENT

- Established in: 2013
- Course offered: B.Tech Mechatronics Engineering
- Approved by AICTE New Delhi and Accredited by NAAC
- Affiliated to the University of Dr. A P J Abdul Kalam Technological University.

DEPARTMENT VISION

To develop professionally ethical and socially responsible Mechatronics engineers to serve the humanity through quality professional education.

DEPARTMENT MISSION

1) The department is committed to impart the right blend of knowledge and quality education to create professionally ethical and socially responsible graduates.

2) The department is committed to impart the awareness to meet the current challenges in technology.

3) Establish state-of-the-art laboratories to promote practical knowledge of mechatronics to meet the needs of the society

PROGRAMME EDUCATIONAL OBJECTIVES

I. Graduates shall have the ability to work in multidisciplinary environment with good professional and commitment.

II. Graduates shall have the ability to solve the complex engineering problems by applying electrical, mechanical, electronics and computer knowledge and engage in lifelong learning in their profession.

III. Graduates shall have the ability to lead and contribute in a team with entrepreneur skills, professional, social and ethical responsibilities.

IV. Graduates shall have ability to acquire scientific and engineering fundamentals necessary for higher studies and research.

PROGRAM OUTCOME (PO'S)

Engineering Graduates will be able to:

PO 1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO 2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO 3. Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO 4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO 5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO 6. The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO 7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO 8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO 9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO 10. Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO 11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO 12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PROGRAM SPECIFIC OUTCOME(PSO'S)

PSO 1: Design and develop Mechatronics systems to solve the complex engineering problem by integrating electronics, mechanical and control systems.

PSO 2: Apply the engineering knowledge to conduct investigations of complex engineering problem related to instrumentation, control, automation, robotics and provide solutions.

COURSE OUTCOME

After the completion of the course the student will be able to

CO 1	Understand the basic concepts in solar energy engineering
CO 2	Describe concepts of bioenergy engineering
CO 3	Interpret about the concepts of wind energy engineering
CO 4	Analyze various energy audit and management techniques
CO 5	Acquire knowledge about waste management techniques
CO 6	Interpret about the concepts technology management

CO VS PO'S AND PSO'S MAPPING

CO	PO1	PO 2	PO3	PO 4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PS0 1	PSO 2
CO 1	3	-	-	-	-	3	3	-	-	-	-	2	-	-
CO 2	3	-	-	-	-	3	3	-	-	-	-	2	-	-
CO 3	3	-	-	-	-	3	3	-	-	-	-	2	-	-
CO 4	3	-	-	-	-	3	2	-	-	-	-	2	-	-
CO 5	3	-	-	-	-	3	3	-	-	-	-	2	-	-
CO 6	3	-	-	-	-	3	2	-	-	-	-	2	-	-

Note: H-Highly correlated=3, M-Medium correlated=2, L-Less correlated=1

SYLLABUS

Course code	Course Name	L-T-P - Credits	Year of Introduction
MR364	Energy Engineering and Management	3-0-0-3	2016

Prerequisite : NIL

Course Objectives

- To study the engineering aspects of solar, wind and bio energy sources.
- To create awareness about the auditing and management techniques related to energy and technology

Syllabus

Solar energy engineering- Bio energy engineering- Wind energy engineering- Energy audit and management- Waste management- Technology management

Expected outcome.

The students will

i. be familiar with the concepts of solar energy engineering, wind energy engineering and bio energy engineering.

ii. grasp the basics of energy auditing techniques, waste management and technology management.

Text Books

1. W R Murphy, G A McKay, Energy Management , Butterworth-Heinemann Ltd
2. S.Rao & B.B.Parulekar, "Energy Technology", 4th edition, Khanna publishers, 2005.
3. Shah, Kanti L., Basics of Solid & Hazardous Waste Management Technology, Printice Hall, 2000
4. Chakraverthy A, "Biotechnology and Alternative Technologies for Utilization of Biomass or Agricultural Wastes", Oxford & IBH publishing Co, 1989.

References:

1. D. Yogi Goswami, Frank Kreith, Jan. F. Kreider, "Principles of Solar Engineering", 2nd Edition, Taylor & Francis, 2000, Indian reprint, 2003 2. Edward E. Anderson, "Fundamentals for solar energy conversion", Addison Wesley Publ. Co., 1983
2. Eastop T.D & Croft D.R, Energy Efficiency for Engineers and Technologists, Logman Scientific & Technical, ISBN-0-582-03184, 1990.
3. Reay D.A, Industrial Energy Conservation, 1stedition, Pergamon Press, 1977.
4. Wind energy Handbook, Edited by T. Burton, D. Sharpe, N. Jenkins and E. Bossanyi, John Wiley & Sons, 2001.

Course Plan

Module	Contents	Hours	Sem. Exam Marks
I	**SOLAR ENERGY ENGINEERING** Source of radiation – solar constant– solar charts – Measurement of diffuse- global and direct solar radiation: pyrheliometer- pyranometer- pyregeometer- net pyradiometer- sunshine recorder. **Photo-voltaic cell** – characteristics-cell arrays-power electric circuits for output of solar panels- choppers-inverters-batteries-charge regulators- Construction concepts.	7	15%
II	**BIO ENERGY ENGINEERING** Sources and Classification. Chemical composition- properties of biomass. Energy plantations .Size reduction- Briquetting- Drying- Storage and handling of biomas-Thermo chemical conversion of lignocelluloses biomass. Incineration- Processing for liquid fuel production.	7	15%

FIRST INTERNAL EXAMINATION			
III	**WIND ENERGY ENGINEERING** Measurement and instrumentation – Beau fort number -Gust parameters – wind type – power law index -Betz constant - Terrain value. Energy in wind– study of wind applicable Indian standards – Steel Tables- Structural Engineering- Grid-combination of diesel generator- Battery storage – wind turbine circuits- Wind farms— fatigue stress	7	15%
IV	**ENERGY AUDIT AND MANAGEMENT** Energy Audit -various Energy Conservation Measures in Steam -Losses in Boiler. Energy Conservation in Steam Systems - Case studies.-Organizational background desired for energy management motivation- detailed process of M&T- Thermostats- Boiler controls- proportional- differential and integral control- optimizers; compensators.	7	15%
SECOND INTERNAL EXAMINATION			
V	**WASTE MANAGEMENT** Sources- Types- Compositions- Properties Physical- Chemical and Biological - Collection - Transfer Stations – Waste minimization and recycling of Municipal Waste. -Size Reduction - Aerobic Composting - Incineration for Medical /Pharmaceutical Waste -Environmental Impacts - Environmental Effects due to Incineration.	7	20%
VI	**TECHNOLOGY MANAGEMENT** Invention- Innovation- Industrial & IPR- Patents- Copyrights- Trademarks- Design Registration- Trade Secrets- WTO- Trade-Patent Specifications- Patent Search Websites. -Technology Transfer Model- Technology Search Strategy- Dimensions of Technology Transfer- Features of Technology Package- Routes of Technology Transfer	7	20%
END SEMESTER EXAM			

QUESTION PAPER PATTERN

Maximum Marks : 100 Exam Duration:3 hours

PART A: FIVE MARK QUESTIONS

8 compulsory questions –1 question each from first four modules and 2 questions each from last two modules (8 x 5= 40 marks)

PART B: 10 MARK QUESTIONS

5 questions uniformly covering the first four modules. Each question can have maximum of three sub questions, if needed. Student has to answer any 3 questions (3 x10 = 30 marks)

PART C: 15 MARK QUESTIONS

4 questions uniformly covering the last two modules. Each question can have maximum of four sub questions, if needed. Student has to answer any two questions (2 x15 = 30 marks)

QUESTION BANK

MODULE I				
Q:NO:	QUESTIONS	CO	KL	PAGE NO:
1	Discuss the various parameters affect the amount of solar radiation to reach the earth.	CO1	K 2	15
2	Compare Direct and Diffused solar radiation.	CO1	K 4	17
3	Discuss the various parameters causes the diffused solar radiation.	CO1	K 2	17
4	What are the main sources of data on solar radiation at the surface of the earth.	CO1	K 1	18
5	Elucidate the working of ground measurement of solar radiations and discuss the types of instruments used for measurement.	CO1	K 2	18
6	Elucidate the working of satellite based measurement of solar radiations and discuss the types of instruments used for measurement.	CO1	K 2	19
7	Define solar constant, and the role of solar constant in solar radiation measurements with neat sketch.	CO1	K 1	21
8	Define solar chart.	CO1	K 1	23
9	Select the different types of solar radiation measuring devices and explain in detail about any two devices with neat sketch.	CO1	K 5	28
10	List the different types of solar radiation measuring devices.	CO1	K 1	28

11	With neat sketch explain in detail about the construction and working of Pyranometer and Pyrheliometer.	CO1	K 3	29
12	Compare Pyranometer and Pyrheliometer.	CO1	K 4	33
13	With neat sketch explain in detail about the construction and working of sunshine recorder and Pyreghometer.	CO1	K 3	33
14	With neat sketch explain in detail about the construction and working of Photovoltaic cell.	CO1	K 3	41
15	List the materials used for manufacturing of photovoltaic cell.	CO1	K1	43
16	List the criteria for choosing materials used for manufacturing of photovoltaic cell.	CO1	K1	43
17	Explain the various components of solar electric energy generating systems with neat block diagram.	CO1	K1	48
MODULE II				
1	Define biomass.	CO2	K1	55
2	Compare Biomass, Bio fuel and Bio energy.	CO2	K4	55
3	List the classification of biofuel by its source.	CO2	K1	56
4	Discuss in detail about the pyrolysis and its types with neat block diagram.	CO2	K3	58
5	Define alcoholic fermentation and list its application.	CO2	K1	59
6	Investigate Anaerobic Digestion of Biogas.	CO2	K6	60
7	What are the main components of the Biomass	CO2	K1	62
8	Interpret the various challenges of the bio mass	CO2	K3	63

9	Interpret biomass properties which are significant to biomass' performance as a fuel.	CO2	K3	63
10	Critique the importance of biofuel over fossil fuel in the real time situation.	CO2	K5	68
11	Investigate in detail about the biomass size reduction techniques.	CO2	K6	72
12	Discuss in detail about briquetting process in biomass.	CO2	K2	72
13	Discuss in detail about drying process in biomass.	CO2	K2	78
14	Discuss the various stages in gasification process. Explain the various processes involved in gasification with neat block diagram.	CO2	K2	79
15	List the benefits and application of the biomass briquetting.	CO2	K1	72
16	List the benefits and application of the biomass drying.	CO2	K1	78
17	Investigate the role of storage and handling of biomass, with necessary equipment's and process.	CO2	K6	82
18	Discuss the various processes in thermochemical conversion of lingo cellulose biomass.	CO2	K2	88
19	Investigate in detail about the Incineration process and its importance.	CO2	K6	91
MODULE III				
1	List the various characteristics of wind.	CO3	K1	93
2	Compare horizontal and vertical axis wind turbines	CO3	K5	97
3	Discuss the various instrument used for wind speed and direction measurements.	CO3	K2	100

4	Discuss in detail about various types of anemometers.	CO3	K2	100
5	Investigate in detail about the Beofort scale of wind.	CO3	K6	102
6	List the Beofort name and representation for thr weather reporting.	CO3	K1	104
7	Discuss in detail about the gust parameters in wind	CO3	K2	111
8	Compare Gust and Wind.	CO3	K5	112
9	Interpret the various types of wind.	CO3	K3	115
10	Discuss in detail about Wind Power index law	CO3	K2	119
11	List the various applications of Wind Power index law.	CO3	K1	120
12	Discuss in detail about Bet's law and Bet's number.	CO3	K2	121
13	Define Bet's Limit.	CO3	K1	122
14	Compare the advantages and disadvantages of wind energy.	CO3	K5	125
15	Discuss in detail about the various innovations in wind tower.	CO3	K2	135
16	Investigate in detail about the construction , working and types of wind turbines.	CO3	K6	141
17	Discuss in detail about the advantages and disadvantages of wind turbines.	CO3	K2	147
18	Explain the types and applications of wind turbines	CO3	K1	156
MODULE IV				
1	Discuss in detail about the process of energy audit and management.	CO4	K2	164
2	Define Energy audit.	CO4	K1	164

3	List the main objectives of energy audit	CO4	K1	165
4	Discuss in detail about the types of energy audit.	CO4	K2	166
5	Compare Preliminary and detailed energy audit	CO4	K5	166
6	Investigate in detail about three Phase of energy audit	CO4	K6	168
7	Discuss the scope of work in detailed energy audit for the current scenario.	CO4	K3	173
8	Elucidate in detail about organization background in energy management.	CO4	K3	176
9	Define energy management	CO4	K1	176
10	Discuss in detail about the roles and responsibities of energy managers.	CO4	K2	181
11	Explain in detail about the motivation of energy managers and its need.	CO4	K1	182
12	Investigate the energy saving methods in steam boilers	CO4	K6	190
13	Discuss the basic functions of steam traps.	CO4	K2	187
14	Discuss in detail about float-thermostat steam traps.	CO4	K2	188
MODULE V				
1	Briefly discuss about the types of solid waste	CO5	K2	199
2	Briefly discuss about the sources of solid waste	CO5	K2	200
3	Briefly discuss about the types of industrial waste	CO5	K2	201
4	Elucidate the basic types and sources of municipal waste.	CO5	K3	202
5	Investigate in detail about the physical and chemical properties of municipal waste.	CO5	K6	206

6	Discuss the various process involved in the solid waste management.	CO5	K2	212
7	Investigate the various composting process for waste management.	CO5	K6	217
8	Elucidate the working of aerobic composting process.	CO5	K3	219
9	With the neat diagram discuss in detail about the incineration process for waste disposal.	CO5	K2	220
10	Interpret the impact of incineration on environment.	CO5	K3	222
11	Discuss in detail about medical waste incineration process.	CO5	K2	223
12	With neat sketch discuss in detail about controlled air, excess air and rotary kiln incinerators for medical waste management.	CO5	K3	226
	MODULE VI			
1	Discuss in detailed about technology management.	CO6	K2	233
2	Discuss in detail about technological innovations.	CO6	K2	234
3	What are the internal factors and external factors affecting the technological innovation?	CO6	K1	238
4	Define Invention.	CO6	K1	244
5	Discuss in detail about the historical evolution and importance of inventions with real time examples.	CO6	K3	244
6	Compare Invention and Innovation.	CO6	K4	252
7	Define IPR.	CO6	K1	255
8	Discuss in detail about forms of protection in IPR.	CO6	K2	256
9	Discuss in detail about patent right	CO6	K2	256
10	Define Copyright.	CO6	K1	259

11	Define Trademark.	CO6	K1	260
12	Discuss in detail about some patent search websites in real time.	CO6	K2	267
13	Investigate in detail about technology transfer process.	CO6	K6	269
14	Discuss about the modes of technology transfer	CO6	K2	278

APPENDIX 1

CONTENT BEYOND THE SYLLABUS

MODULE 1

SOLAR ENERGY ENGINEERING

INTRODUCTION

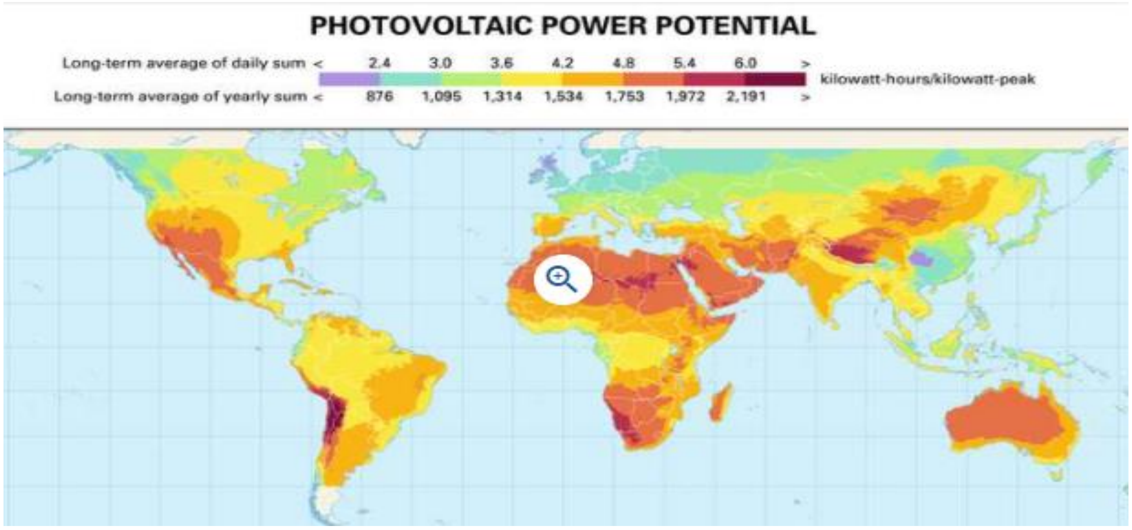
Solar radiation, often called the solar resource or just sunlight, is a general term for the electromagnetic radiation emitted by the sun. Solar radiation can be captured and turned into useful forms of energy, such as heat and electricity, using a variety of technologies. However, the technical feasibility and economical operation of these technologies at a specific location depends on the available solar resource.

BASIC PRINCIPLES

Every location on Earth receives sunlight at least part of the year. The amount of solar radiation that reaches any one spot on the Earth's surface varies according to:

- Geographic location
- Time of day
- Season
- Local landscape
- Local weather.

Because the Earth is round, the sun strikes the surface at different angles, ranging from 0° (just above the horizon) to 90° (directly overhead). When the sun's rays are vertical, the Earth's surface gets all the energy possible. The more slanted the sun's rays are, the longer they travel through the atmosphere, becoming more scattered and diffuse. Because the Earth is round, the frigid polar regions never get a high sun, and because of the tilted axis of rotation, these areas receive no sun at all during part of the year.



The Earth revolves around the sun in an elliptical orbit and is closer to the sun during part of the year. When the sun is nearer the Earth, the Earth's surface receives a little more solar energy. The Earth is nearer the sun when it is summer in the southern hemisphere and winter in the northern hemisphere. However, the presence of vast oceans moderates the hotter summers and colder winters one would expect to see in the southern hemisphere as a result of this difference.

The 23.5° tilt in the Earth's axis of rotation is a more significant factor in determining the amount of sunlight striking the Earth at a particular location. Tilting results in longer days in the northern hemisphere from the spring (vernal) equinox to the fall (autumnal) equinox and longer days in the southern hemisphere during the other 6 months. Days and nights are both exactly 12 hours long on the equinoxes, which occur each year on or around March 23 and September 22.

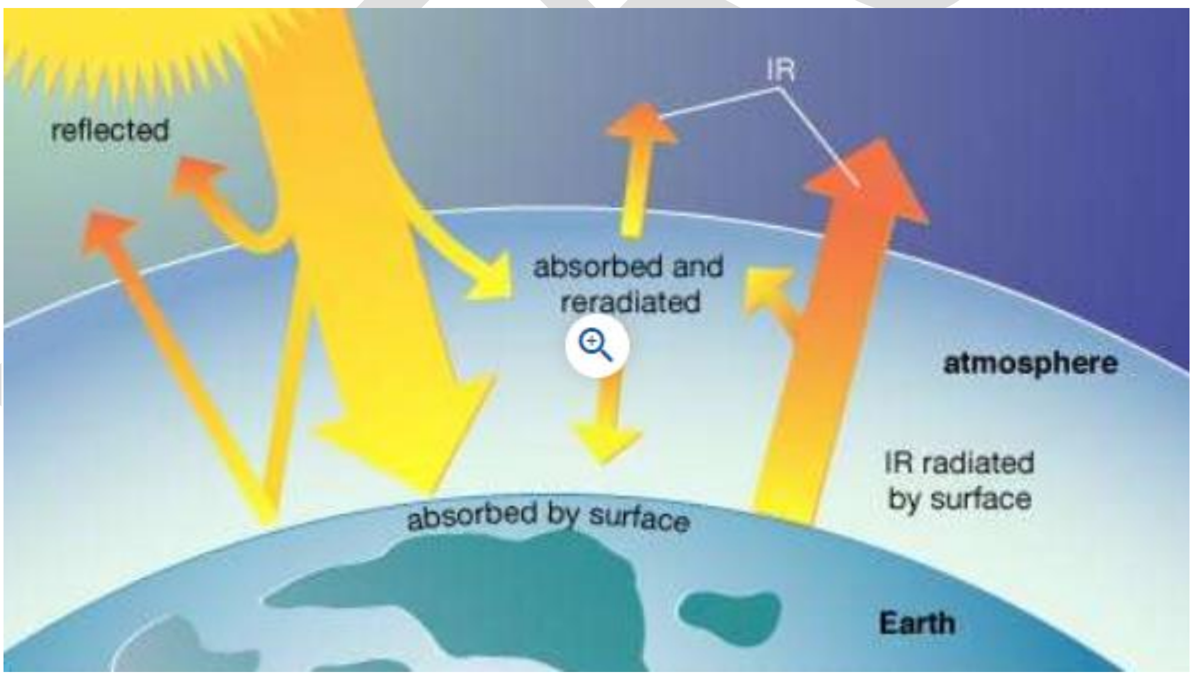
Countries such as the United States, which lie in the middle latitudes, receive more solar energy in the summer not only because days are longer, but also because the sun is nearly overhead. The sun's rays are far more slanted during the shorter days of the winter months. Cities such as Denver, Colorado, (near 40° latitude) receive nearly three times more solar energy in June than they do in December.

The rotation of the Earth is also responsible for hourly variations in sunlight. In the early morning and late afternoon, the sun is low in the sky. Its rays travel further through the atmosphere than at noon, when the sun is at its highest point. On a clear day, the greatest amount of solar energy reaches a solar collector around solar noon.

DIFFUSE AND DIRECT SOLAR RADIATION

As sunlight passes through the atmosphere, some of it is absorbed, scattered, and reflected by:

- Air molecules
- Water vapor
- Clouds
- Dust
- Pollutants
- Forest fires
- Volcanoes.



This is called diffuse solar radiation. The solar radiation that reaches the Earth's surface without being diffused is called direct beam solar radiation. The sum of the diffuse and direct solar radiation is called global solar radiation. Atmospheric conditions can reduce direct beam radiation by 10% on clear, dry days and by 100% during thick, cloudy days.

MEASUREMENT

Scientists measure the amount of sunlight falling on specific locations at different times of the year. They then estimate the amount of sunlight falling on regions at the same latitude with similar climates. Measurements of solar energy are typically expressed as total radiation on a horizontal surface, or as total radiation on a surface tracking the sun.

Radiation data for solar electric (photovoltaic) systems are often represented as kilowatt-hours per square meter (kWh/m^2). Direct estimates of solar energy may also be expressed as watts per square meter (W/m^2).

Radiation data for solar water heating and space heating systems are usually represented in British thermal units per square foot (Btu/ft^2).

DISTRIBUTION

The solar resource across the United States is ample for photovoltaic (PV) systems because they use both direct and scattered sunlight. Other technologies may be more limited. However, the amount of power generated by any solar technology at a particular site depends on how much of the sun's energy reaches it. Thus, solar technologies function most efficiently in the southwestern United States, which receives the greatest amount of solar energy.

TYPES OF SOLAR RADIATION DATA SOURCES

The two main sources of data on solar radiation at the surface of the earth are:

- Ground measurements
- Calculations based on satellite data

GROUND MEASUREMENTS OF SOLAR RADIATION

Direct measurements of the solar radiation at ground level can be made with a number of different instruments. One widely used instrument is the **pyranometer**. Typically, the instrument measures all the radiation coming from the sun and from the sky or clouds. When you want to know the solar radiation at a specific place, ground station measurements give the best results. It is also possible to measure with a high time resolution, typically every minute or even more often.

Possible problems with the measurements, apart from failure in the measurement system itself, is that the sensor may be covered with dirt, frost, or snow, or that the sensor is shadowed by nearby trees or buildings for some of the time during the year. These problems can be removed by careful siting and maintenance, but it makes it more uncertain to use data where you don't have direct experience with the measurements. Most of these potential problems will cause the measurement readings to be too low.

When there are no direct measurements at a given place, it is still possible to estimate the solar radiation from measurements made nearby. Of course the quality of the estimate will decrease as the distance to the measurement site increases. It is also possible to combine data from several different measurement locations to make an estimate for the solar radiation in a place somewhere between the measurement sites. This method is used in the original PVGIS solar radiation database for Europe.

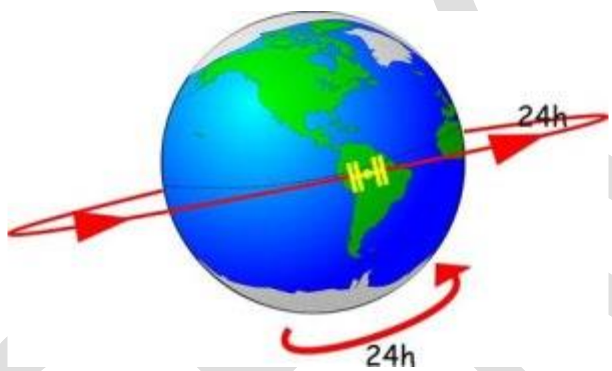
pyranometer

SOLAR RADIATION ESTIMATES FROM SATELLITE

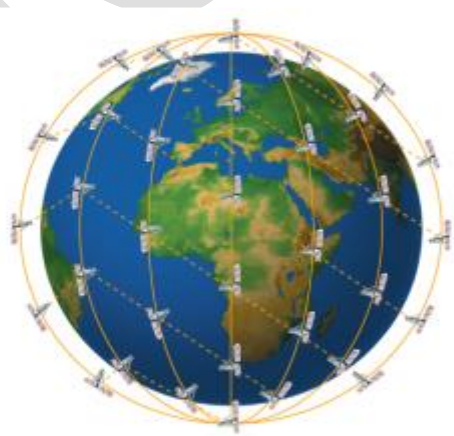
There are a number of methods to estimate the solar radiation at ground level using data from satellites. Typically the satellites measure the light (visible or infrared) coming from the Earth.

This light is mainly the light reflected from the ground or from clouds. The calculation of the solar radiation at ground level must therefore be able to take into account the radiation absorbed by the atmosphere as well as that reflected by clouds.

Different types of satellites can be used to estimate solar radiation. ***Geostationary*** weather satellites take pictures of the Earth at short intervals (every 15 or 30 minutes) so have a very good time resolution. However, each pixel in the picture typically represents a rectangle a few km on each side, so the estimate of solar radiation for each pixel will be the average of such an area.



Polar-orbiting satellites fly closer to the Earth, so the space resolution is better. However, they don't stay permanently above a particular area, so they are normally able to take only a couple of pictures a day of a given area. The data used for PVGIS come mainly from geostationary satellites.



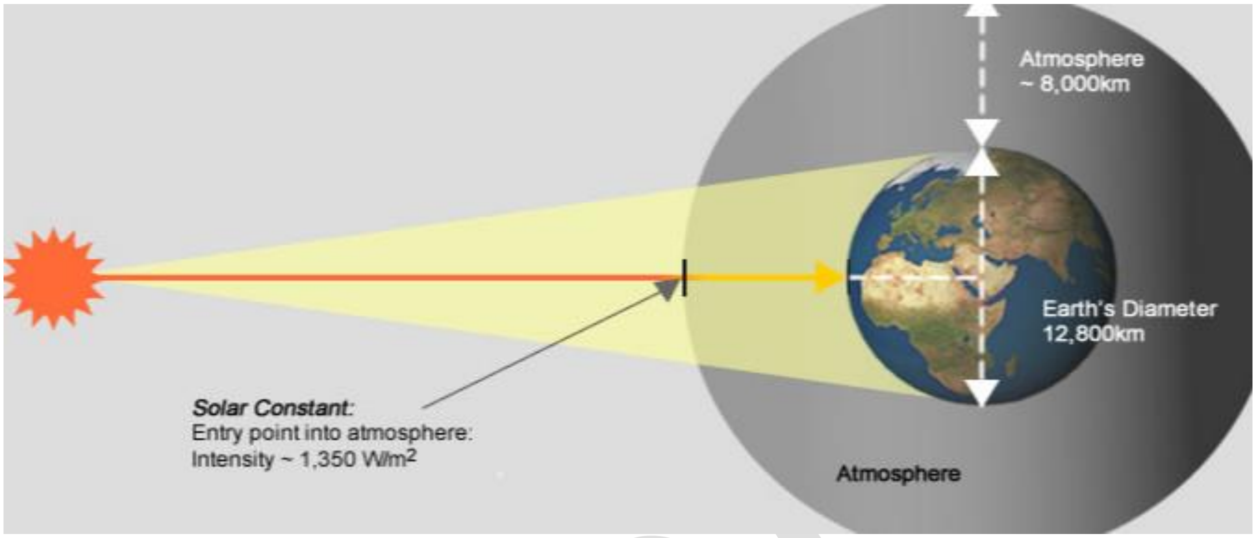
The main advantage of satellite-based methods is that they give a fairly uniform coverage of large areas while ground stations are often very far apart. On the other hand, there are potential problems also with the satellite methods:

- Snow on the ground is a special problem for satellite methods, since snow will look very much like clouds in the satellite images. There are methods to overcome this problem, but the uncertainty is higher in areas with snow.
- In mountain areas one pixel may cover an area with strongly varying altitude. The solar radiation dependence on altitude is not well represented in the satellite-based calculations.
- When the sun is very low in the sky the calculation from satellite data becomes very difficult. This can cause problems, in particular in winter at high latitudes.

The quality of satellite-based estimates must be checked by comparison with high-quality ground station measurements.

SOLAR CONSTANT

The solar constant is a measure of the power of a square meter of sunlight directly impacting on a perpendicular plane of space above the atmosphere of the Earth, and is considered to be a uniform value of 1,370 watts per square meter. This changes dramatically, however, at the surface of the Earth, as sunlight has to pass through varying layers of atmosphere depending on latitude and sea level as well as atmospheric conditions. Therefore, the solar constant is largely a reference number used off of which to base actual sunlight values received, and is instrumental in such areas as the placement of solar arrays for photovoltaic or **solar furnace** power generation, and in weather and agricultural calculations. As a pure value above the limits of the atmosphere, the solar constant also varies by 3% depending on the point at which the Earth is in its orbit of the Sun, since the orbit is slightly elliptical.



The entire spectrum of electromagnetic radiation is included in the measurement of a solar constant and not just that of visible light. The best direct measurements of the solar constant are taken from satellites. The Stefan-Boltzman constant can also be used as a means to calculate a solar constant. In this context, the constant defines the power per unit area emitted by a black body as a function of its thermodynamic temperature.

While solar radiation values for the solar constant usually focus on visible light, the values are a calculation of all solar electromagnetic radiation received. This includes infrared light, X-rays, and radio waves that are transmitted by the Sun, though high frequency waves like X-rays make up less than 1% of the total energy emitted. Where sunlight has reached the Earth's surface, this radiation is referred to as insolation, and has an optimal level of around 1,000 watts per square meter. Practical values due to higher latitudes, varying elevations, overcast skies, and other causes for indirect light drop this value to 250 watts per square meter, reducing the actual solar energy level that the Earth receives in space by a factor of more than five once it reaches the surface.

The solar constant is an important value to know in the field of **satellite** and space probe development. This is due to the fact that these systems often have solar panels for generating power, and that they can be damaged by some solar radiation if not properly shielded. Research into solar cycles for the Sun, involving the calculation of solar storms and sunspot activity, are also dependent on the solar constant and its level of flux density or the relative amount of **solar**

power transmitted per square meter. The Sun itself is known to have a slight variability to its radiation levels over 11-year cycles of ±0.2%. This along with a 10% increase in the solar constant every 10,000,000,000 years can have dramatic impacts on Earth's climate in regional areas such as the sea or on a global basis over time.

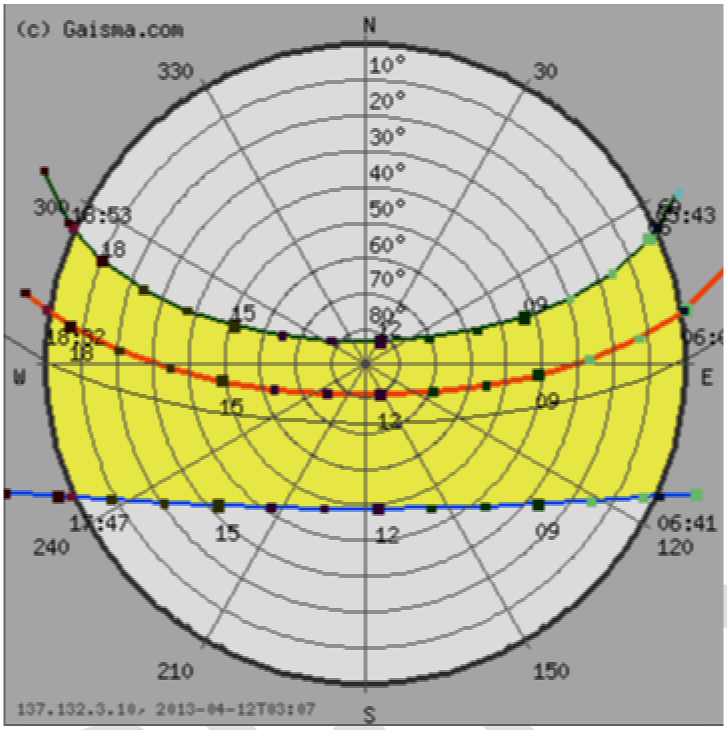
Manned space exploration to locations such as the Earth's Moon or the planet Mars also have to take into account the solar constant for these regions. Solar energy is largely similar to the pure value for Earth when on the Moon's surface, due to the same relative distance from the Sun and the fact that the Moon has no atmosphere. Mars, however, will have a different solar constant due to it being at any one time at least 30,000,000 miles (48,280,320 kilometers) farther from the Sun than the Earth, and because it has its own weak atmosphere. In space or on barren planets and asteroids, the solar constant is the primary indicator of how much energy is available for processing rocks into useful materials such as **oxygen** and **hydrogen**, or for generating electrical power to sustain artificial environmental systems and communications equipment.

SUN CHART

A **Sun chart** is a graph of the ecliptic of the Sun through the sky throughout the year at a particular latitude.

Most sun charts plot azimuth versus altitude throughout the days of the winter solstice and summer solstice, as well as a number of intervening days. Since the apparent movement of the Sun as viewed from Earth is nearly symmetrical about the solstice, plotting dates for one half of the year gives a good approximation for the rest of the year. Thus, to simplify the diagram, some sun charts show days for different months as the same, e.g. March 21 equals September 21. The accompanying sun chart for Berlin accounts for deviations in symmetry between the two halves of the year through the use of the analemma, represented by each figure eight on the chart.

The graph may show the entire horizon or only that half of the horizon closest to the equator. Sky view obstructions can be superimposed upon a Sun chart to obtain the insolation of a location.



MEASUREMENT OF SOLAR RADIATION

Radiation

It is important to measure solar radiation, owing to the increasing number of solar heating and cooling applications, and the necessity for accurate solar radiation data to predict performance.

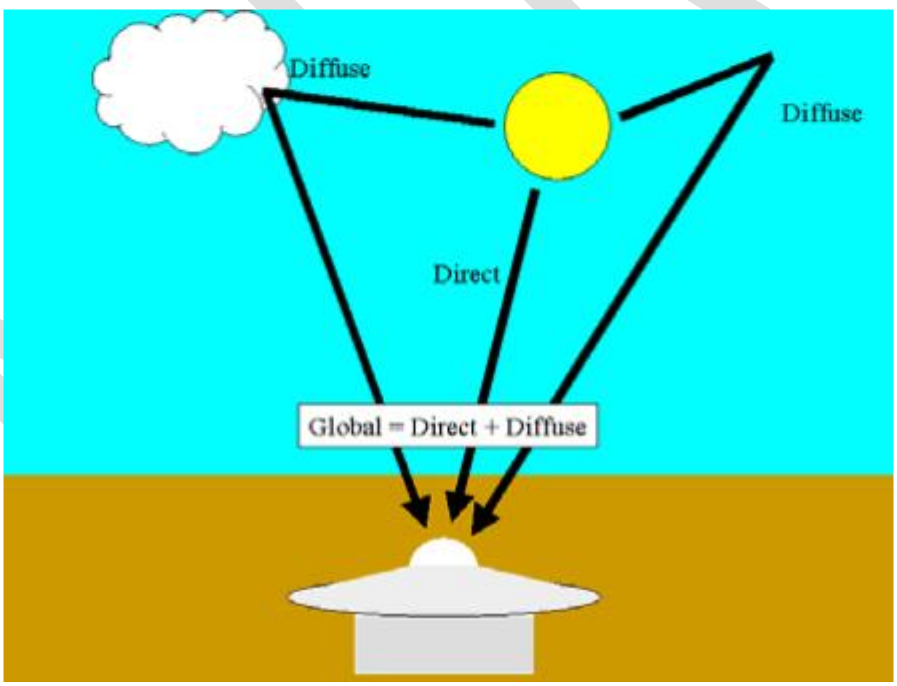
Solar radiation is a term used to describe visible and near-visible (ultraviolet and near-infrared) radiation emitted from the sun. The different regions are described by their wavelength range within the broad band range of 0.20 to 4.0 µm (microns). Terrestrial radiation is a term used to describe infrared radiation emitted from the atmosphere. The following is a list of the components of solar and terrestrial radiation and their approximate wavelength ranges:

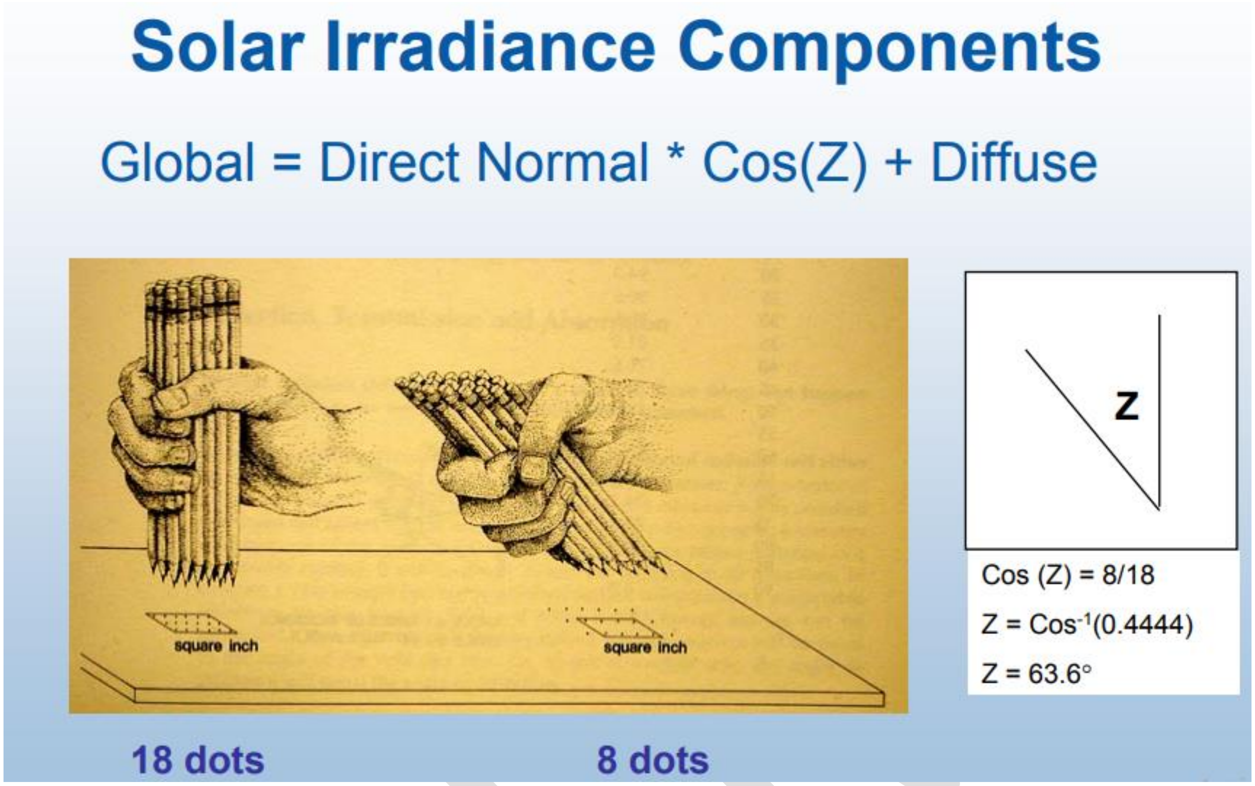
- Ultraviolet: 0.20 – 0.39 µm
- Visible: 0.39 – 0.78 µm

- Near-Infrared: 0.78 – 4.00 µm
- Infrared: 4.00 – 100.00 µm

Approximately 99% of solar, or shortwave, radiation at the earth's surface is contained in the region from 0.3 to 3.0 µm while most of terrestrial, or longwave, radiation is contained in the region from 3.5 to 50 µm.

Outside the earth's atmosphere, solar radiation has an intensity of approximately 1370 watts/meter^2. This is the value at mean earth-sun distance at the top of the atmosphere and is referred to as the Solar Constant. On the surface of the earth on a clear day, at noon, the direct beam radiation will be approximately 1000 watts/meter^2 for many locations. While the availability of energy is affected by location (including latitude and elevation), season, and time of day, the biggest factors affecting the available energy are cloud cover and other meteorological conditions which vary with location and time.





Ultraviolet Measurements

For the measurement of sun and sky ultraviolet radiation in the wavelength interval 0.295 to 0.385 µm, which is particularly important in environmental, biological, and pollution studies the Total Ultraviolet Radiometer (Model TUVR) was developed. This instrument utilizes a photoelectric cell protected by a quartz window. A specially designed teflon diffuser not only reduces the radiant flux to acceptable levels but also provides close adherence to the Lambert cosine law. An encapsulated narrow bandpass (interference) filter limits the spectral response of the photocell to the wavelength interval 0.295-.0385 µm.

Shortwave Measurements: Direct, Diffuse And Global

As solar radiation passes through the earth's atmosphere, some of it is absorbed or scattered by air molecules, water vapor, aerosols, and clouds. The solar radiation that passes through directly to the earth's surface is called Direct Normal Irradiance (DNI). The radiation that has been scattered out of the direct beam is called Diffuse Horizontal Irradiance (DHI). The direct component of sunlight and the diffuse component of skylight falling together on a horizontal surface make up Global Horizontal Irradiance (GHI). The three components have a geometrical relationship.

Direct radiation is best measured by use of a pyrheliometer, which measures radiation at normal incidence. The Normal Incidence Pyrheliometer (Model sNIP) consists of a wirewound thermopile at the base of a tube with a viewing angle of approximately 5º which limits the radiation that the thermopile receives to direct solar radiation only.

The pyrheliometer is mounted on a Solar Tracker (Models ST-1 and ST-3) or an Automatic Solar Tracker (Model SMT) for continuous readings.

Diffuse radiation can either be derived from the direct radiation and the global radiation or measured by shading a pyranometer from the direct radiation so that the thermopile is only receiving the diffuse radiation. Eppley has developed Shade Disk Adaption Kit (Model SDK) that mounts on the SMT which allows you to measure the diffuse and direct at the same time. We also manufacture the Shadow Band Stand, (Model SBS) for Diffuse measurements in sites where there is no power available to operate an Automatic Tracker.

Global radiation is measured by a pyranometer. The modern pyranometer manufactured by the Eppley Laboratory, using wirewound plated thermopiles, can be one of three models: the Standard Precision Pyranometer (Model SPP), the Global Precision Pyranometer (Model GPP), and the Black & White Pyranometer (Model 8-48). The SPP has a black sensor protected by two precision ground, polished hemispheres and is the preferred instruments for Global measurements. Based on the SPP, the GPP is specifically designed as a lower cost alternative for the PV/CSP industry. The 8-48 has a black and white sensor that is protected by a single polished hemisphere and is the preferred instrument for Diffuse measurements.

Longwave (Infrared) Measurements

The Precision Infrared Radiometer, (Model PIR) was a development of the PSP Pyranometer (forerunner to the SPP Pyranometer) and continues to be the industry standard for precise measurement of incoming or outgoing longwave radiation. The PIR comprises the same wirewound thermopile detector and temperature compensation circuitry as found in the PSP/SPP. This thermopile detector is used to measure the "net radiation" of the PIR and a case thermistor

(YSI 44031) is used to determine the outgoing radiation from the case. A dome thermistor is also included if one wishes to measure the dome temperature as compared to the case temperature to make any “corrections” to the final result.

Albedo / Bifacial Measurements

Albedo is the ratio of incoming shortwave divided by the reflected shortwave on a horizontal plane. The best way to measure albedo is with two distinct pyranometers – one facing upward and the other facing downward. The smaller, lightweight GPP is perfect for these measurements. If one tilts the UP/DOWN orientation of these two instruments to match the orientation of their PV array, they are able to measure the Plane of Array Irradiance (POA or Gi) and the In-Plane Rearside Irradiance (G_i^{REAR}) for Bifacial testing.

Net Radiation Measurements

Net radiation is the sum of four individual measurements: Incoming Shortwave, Reflected Shortwave, Incoming Longwave and Outgoing Longwave. Eppley recommends measuring each of the four componants separately using two (2) SPPs and two (2) PIRs.

Sunshine Duration Measurements

Sunshine duration is typically defined as the amount of time that the Direct Normal Irradiance (DNI) is greater than 120 Wm^{-2}. This can be determined by using the data collected from the sNIP.

SOLAR RADIATION MEASURING DEVICES

These are some devices which is used to measurement of solar radiation.

Types of Solar Radiation measuring devices

1. Pyranometer
2. Pyrneliometers
3. Sunshine Recorders

4. Pyregeometer
5. Pyradiometer

PYRANOMETER

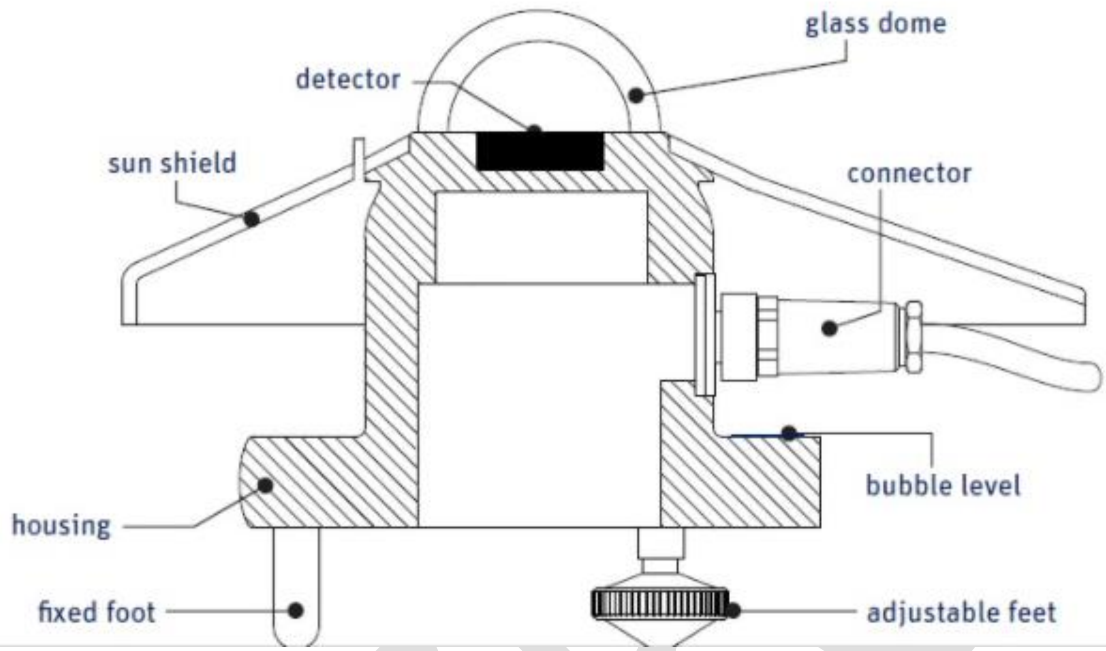
A Pyranometer is a device use to measure the "total hemispherical solar radiation". The total solar radiation arriving at the outer edge of the atmosphere is called the "Solar constant".

The working principle of this instrument is that sensitive surface is exposed to total (beam, diffuse and reflected from the earth and surrounding) radiations.

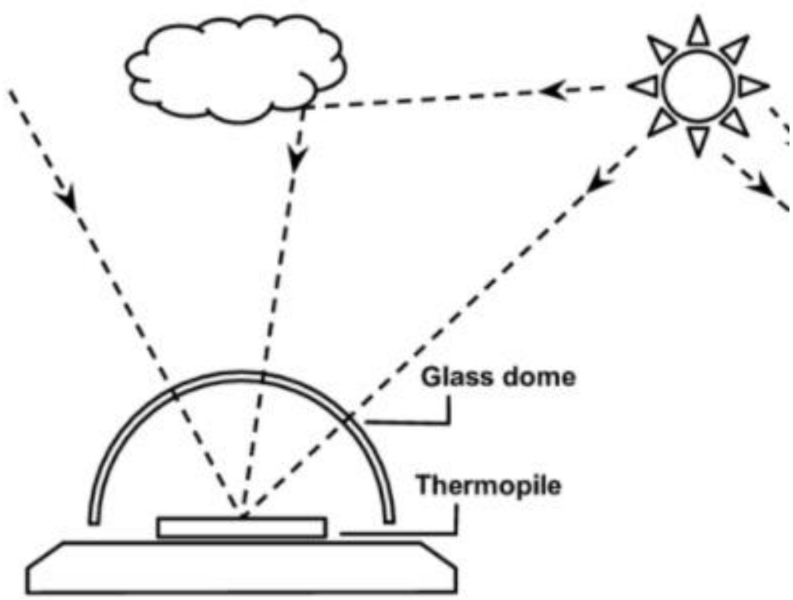
Construction

It consists of black surface which receives the beam as well diffuse radiations which rises het. A Glass some prevents the loss of radiation received by the black surface.

A thermocouple is a temperature sensor, and consists of a number of thermocouples connected in series to increase the sensitivity. The supporting stand keeps the black surface in a proper position.



Working of pyranometer



When the pyronometer is exposed to sun, it starts receiving the radiations. As a result, the surface temperature starts rising due to absorption of the radiation. The increase in the temperature of the absorbing surface is detected by the thermopile. The thermopile generates a thermo emf which is proportional to the radiations absorbed.

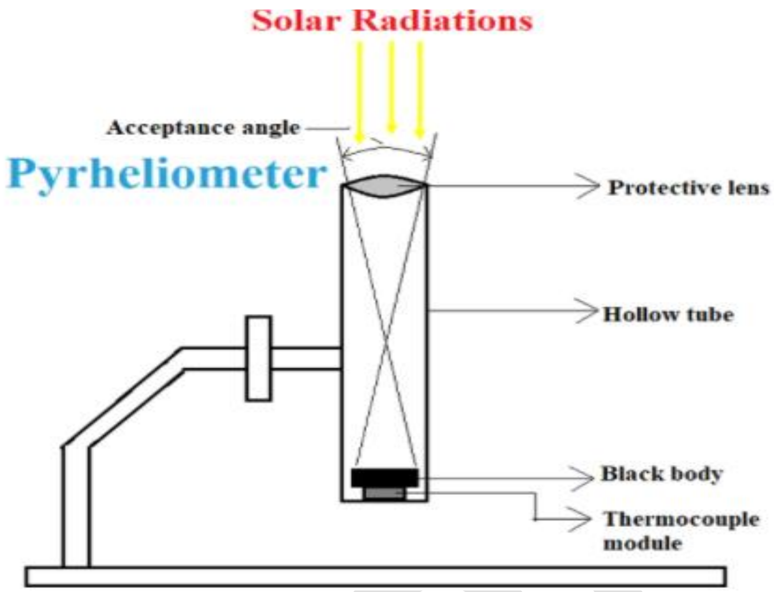
This will measure global solar radiations.

PYRHELIOMETER

A pyrhelimeter is a device used to measure beam or direct radiations. It is collimates the radiation to determine the beam intensity as a function of incident angle.This instrument uses a collimated detector for measuring solar radiation from the sun and from a small portion of the sky around the sun at normal incidence.

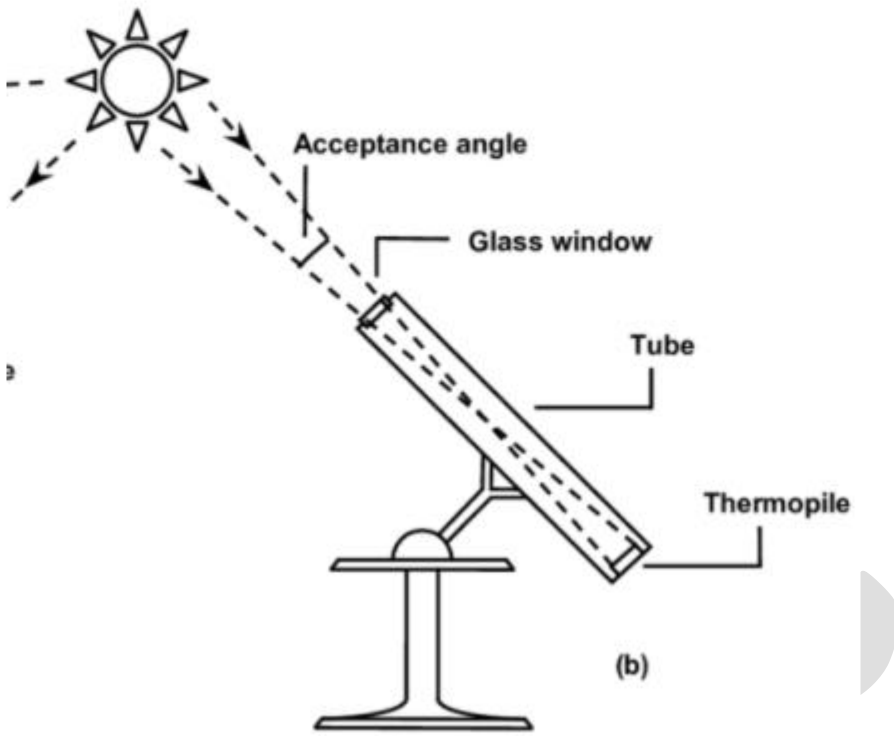
Construction

In this instrument, two identical blackened magnin strips A and B are arranged in such a way that either can be exposed to radiation the base of collimating tubes by moving a reversible shutter.



Working of prheliometer

One strip is placed in radiation and a current is passed through the shaded strip to heat it to the same temperature as the exposed strip. When there is no difference in temperature, the electrical energy supplied to shade strip must equal the solar radiation absorbed by the exposed strip. Solar radiation is then determined by equating the electrical energy to the product of incident solar radiation, strip area and absorptance. these are use in measurement of solar radiation.



Difference between Pyrheliometer and Pyranometer

Both the instruments like Pyrheliometer & Pyranometer are used to calculate solar irradiance. These are related in their intention but there are some dissimilarities in their construction & working principle.

PYRHELIOMETER	PYRANOMETER
his instrument is used to measure direct ray solar irradiance.	It is one kind of acidometer mainly used to measure the solar irradiance over a planar surface.
In this, the thermoelectric detection principle is used	It uses thermoelectric detection principle

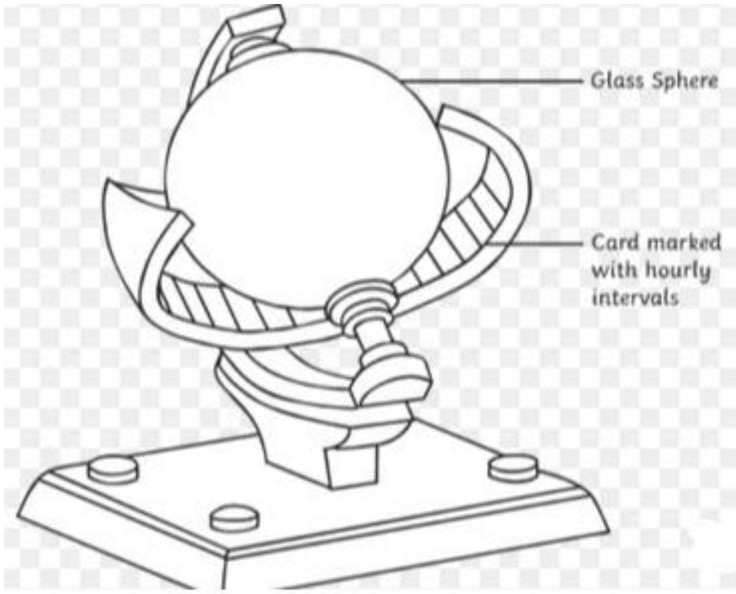
In this, the increasing temperature can be calculated through thermocouples that are allied in series/series-parallel to create a thermopile.	In this, the measurement of increasing temperature can be done through thermocouples which are linked in series otherwise series-parallel to build a thermopile.
This is also used in meteorological research stations	This is frequently used in meteorological research stations
This instrument calculates direct solar radiation.	This instrument calculates global solar radiation.

SUNSHINE RECORDER

A sunshine recorder is a device used to measure the hours of bright sunshine in a day.

Construction

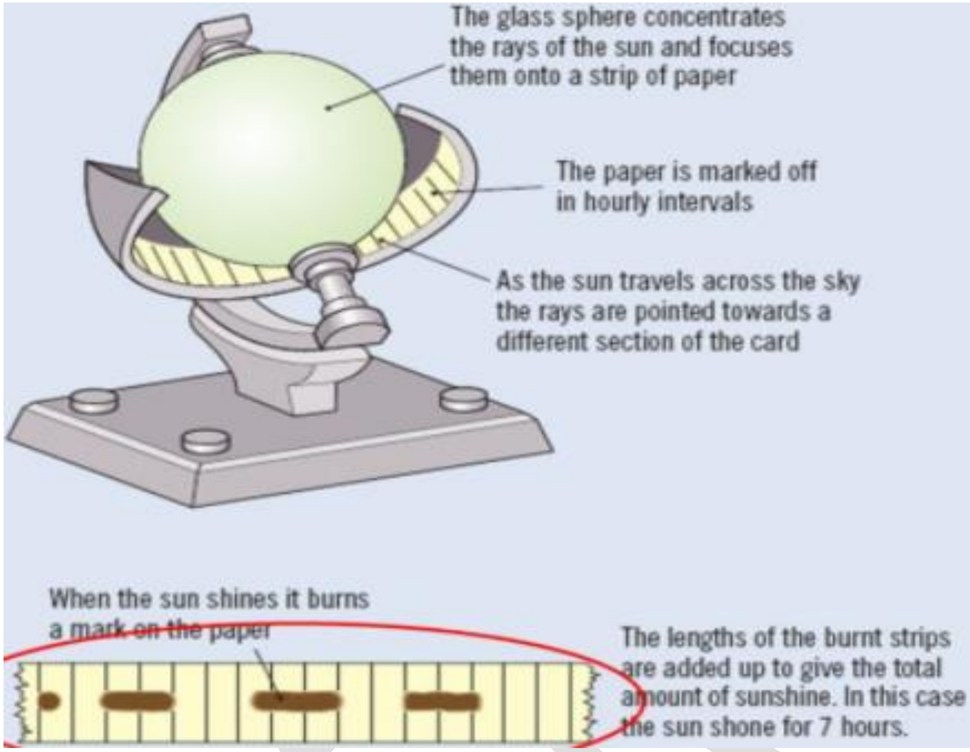
It consists of a “glass-sphere” installed in a section of “spherical metal bowl” having grooves for holding a “recorder card strip” and the glass sphere.



Working of Sunshine Recorder

The glass sphere, which acts as a convex lane, focuses the sun's rays/beams to a point on the card strip held in a groove in the spherical bowl mounted concentrically with the sphere.

Whenever there is a bright sunshine, the image formed is intense enough to burn a spot on the card strip. Through the day, the sun moves across the sky, the image moves along the strip. Thus a burnt space whose length is proportional to the duration of sunshine is obtained on the strip.

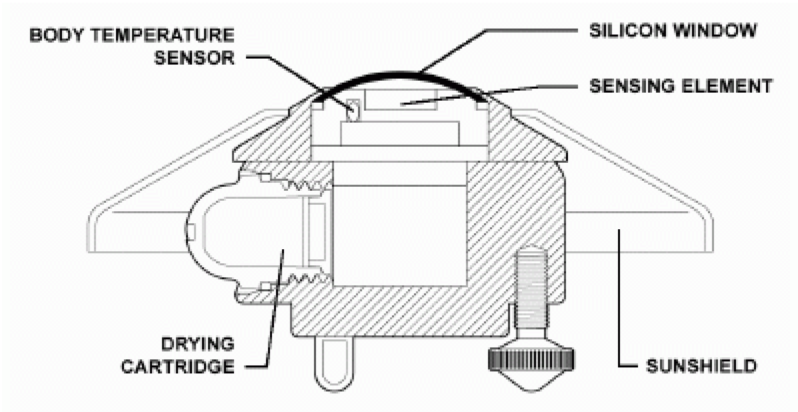


PYREGEOMETER

A pyrgeometer is an instrument for measuring the infrared radiation spectrum in the atmosphere, which extends from 4,5 µm to 100 µm.

This instrument is sensitive to both short- and long-wave radiation in different ways. It is designed for material testing research as well as for atmospheric applications.

Long-wave radiation is emitted by all objects in the universe. However, the main purpose of a pyrgeometer is to assist in meteorological observations of atmospheric radiation by measuring the net radiation difference between the earth and the atmosphere.



Working Principle

The pyrgeometer works based on the principle that radiant energy is converted into heat energy, and that this energy can be measured by a thermopile.

This instrument consists of a silicone dome to isolate long-wave radiation from solar short-wave radiation during daylight hours. It also includes a vacuum-deposited interference filter with a transmission range of approximately 3.5 µm to 50 µm, and a shielded case to minimize the heating of the instrument from solar radiation.

Thermistors are employed to monitor the temperatures of the dome, case, and environmental thermal infrared irradiance.

A detector coated with black paint senses a net signal from various sources including emissions from the dome, case, and targets in its field of view.

The incoming radiation is absorbed by the detector, and the heat flows through the instrument body. The thermal gradient across the thermopile creates a voltage that is relative to the net radiation.

The spectral range of the incoming radiation is restricted by the filter that eliminates unwanted solar radiation. Thus, the thermal infrared irradiance can be measured in watts per square meter (W/m^2).

The case is protected from solar radiation and its temperature is considered as the air temperature, which enables the device to provide the degree of thermal emission by the atmosphere. Conversely, the dome is unprotected from heat. Therefore, the difference between thermal emissions of the dome and case provides an erroneous signal which has to be eliminated.

Applications

Atmospheric radiation from water vapor, clouds, and CO_2 are the core subjects of measurement for the pyrgeometer. It is also used for material testing research applications and low-temperature applications of the sensors applied in aircraft observations.

PYRADIOMETER

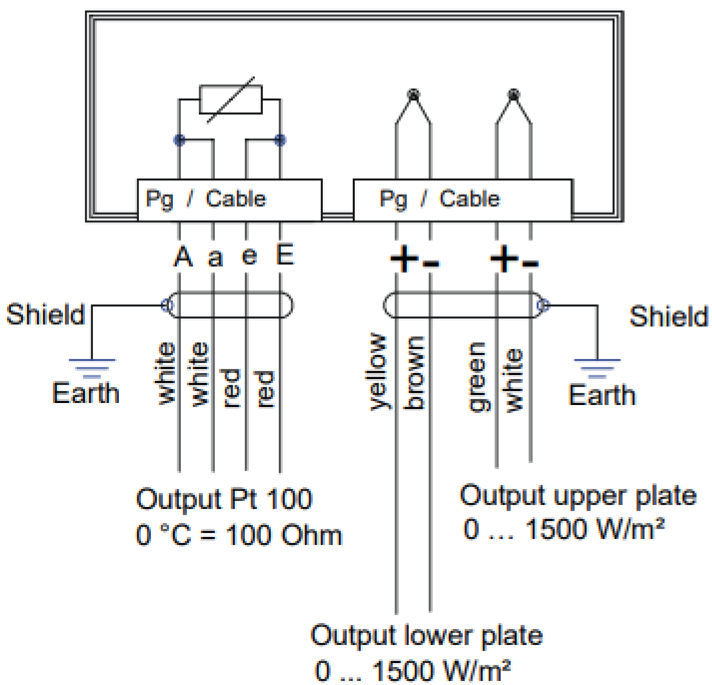
The Pyrradiometer is used for exact determination of net radiation in short- and long wave radiation range with two separately working receivers and with built-in Pt 100 resistant Thermometer to determine reference temperature. The measuring principle of the Pyrradiometer is the measurement of the temperature difference between blackened receiver plates facing up and blackened receiver plates facing down by means of thermocouple elements.

Construction and Mode of Operation

Between two blackened receiver plates a sturdy Aluminium heat sink is located in the centre of the instrument. Under each of the two black surfaces are placed a cluster of thermocouples connected in series. As the radiation flux is transformed thermoelectrically and the measurement is based on temperature differences, the heat sink temperature is determined by means of a built-in resistance Thermometer. When only net radiation is to be determined heat sink temperatures are not to be considered. The lupolene domes shield the receiver plates from wind and moisture and are fastened water light by screw rings and O-rings. Two tubes of desiccant are supplied to remove vapour from inside the housing. Two levels are imbedded in the top and bottom of the instrument. An arm with holes for mounting is included.

Mounting

The place where the instrument is located should not be shaded by high buildings, trees or others and for regular maintenance it should be easily accessible. The distance from the reference surface should be 1 – 1,5 m maximum. Only in case large surfaces are measured the distance can be higher. The outputs of the cable should be directed to north. The radiation of the atmosphere should be measured by the receiver with the green and white print. It is recommended to record the global radiation together with the measurement of the device temperature. Final levelling is accomplished with the incorporated bull's-eye level on each side of the equipment. The colour of the cables corresponds to the colour code of the receiver plate



Evaluation

When using instruments for long-wave radiation , the radiation caused by the temperature of the instrument itself, and being emitted over the receiving surface of the instrument, must be taken into consideration. Therefore, it is necessary to record the instrument temperature and to correct the measured radiation values accordingly.

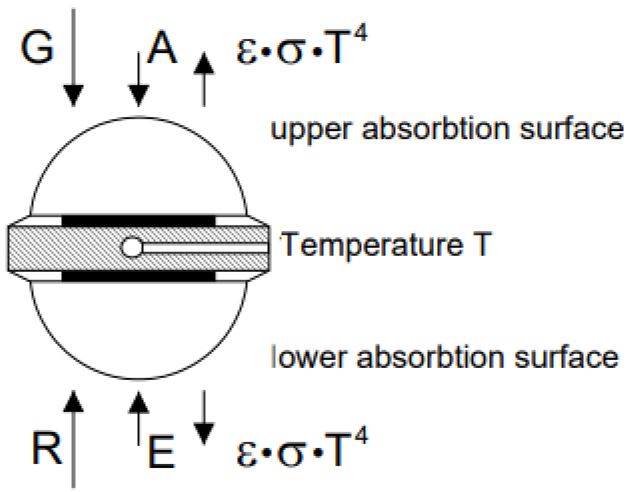


PHOTO VOLTAIC CELL (SOLAR CELL)

The Photovoltaic cell is the semiconductor device that converts the light into electrical energy. The voltage induces by the PV cell depends on the intensity of light incident on it. The name Photovoltaic is because of their voltage producing capability.

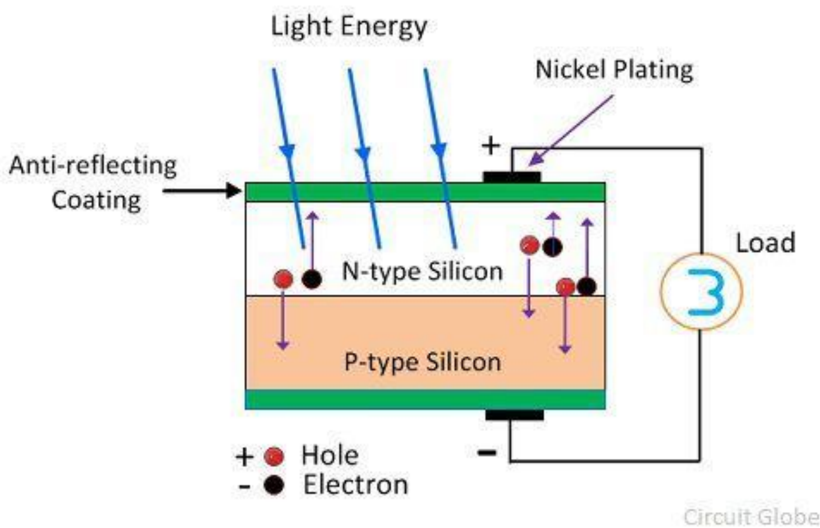
The electrons of the semiconductor material are joined together by the covalent bond. The electromagnetic radiations are made of small energy particles called photons. When the photons are incident on the semiconductor material, then the electrons become energised and starts emitting.

The energises electron is known as the Photoelectrons. And the phenomenon of emission of electrons is known as the photoelectric effect. The working of the Photovoltaic cell depends on the photoelectric effect.

Construction of Photovoltaic Cell

The semiconductor materials like arsenide, indium, cadmium, silicon, selenium and gallium are used for making the PV cells. Mostly silicon and selenium are used for making the cell.

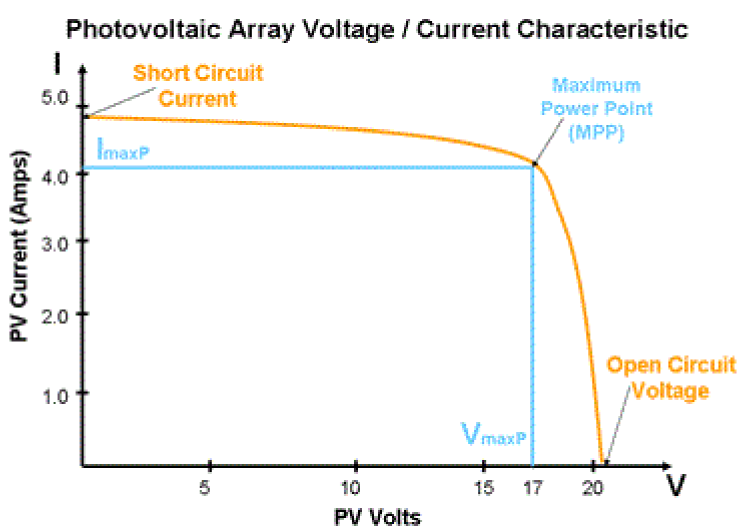
Consider the figure below shows the constructions of the silicon photovoltaic cell. The upper surface of the cell is made of the thin layer of the p-type material so that the light can easily enter into the material. The metal rings are placed around p-type and n-type material which acts as their positive and negative output terminals respectively.



The multi-crystalline or mono crystalline semiconductor material make the single unit of the PV cell. The mono-crystal cell is cut from the volume of the semiconductor material. The multi cell are obtained from the material which has many sides.

The output voltage and current obtained from the single unit of the cell is very less. **The magnitude of the output voltage is 0.6v, and that of the current is 0.8A.** The different combinations of cells are used for increasing the output efficiency. There are three possible ways of combining the PV cells.

V-I Characteristics of a Photovoltaic Cell



Materials Used in Solar Cell

The materials which are used for this purpose must have band gap close to 1.5ev. Commonly used materials are-

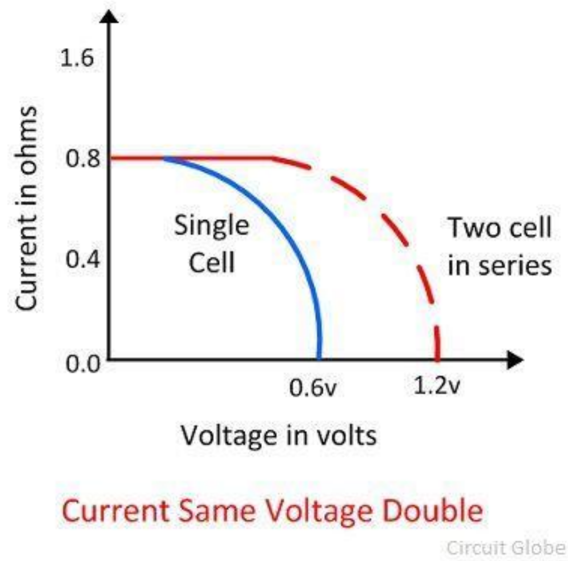
1. Silicon.
2. GaAs.
3. CdTe.
4. $CuInSe_2$

Criteria for Materials to be used in Solar Cell

1. Must have band gap from 1ev to 1.8ev.
2. It must have high optical absorption.
3. It must have high electrical conductivity.
4. The raw material must be available in abundance and the cost of the material must be low.

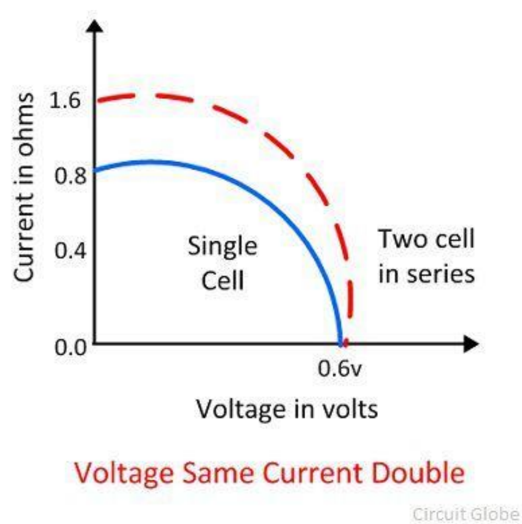
Series Combination of PV Cells

If more than two cells are connected in series with each other, then the output current of the cell remains same, and their input voltage becomes doubles. The graph below shows the output characteristic of the PV cells when connected in series.



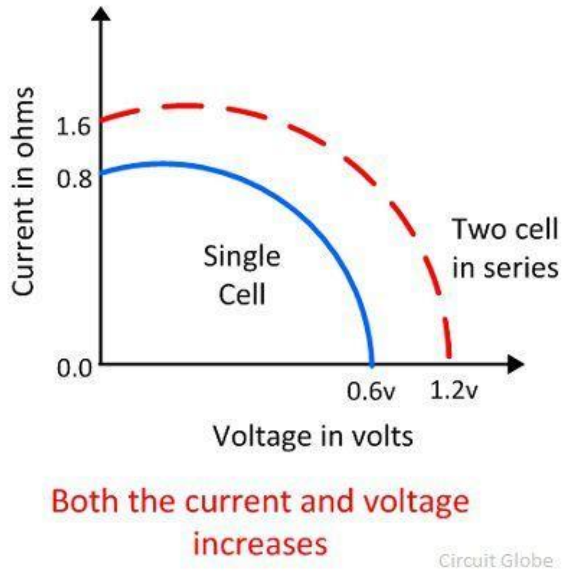
Parallel Combination of PV cells

In the parallel combination of the cells, the voltage remains same, and the magnitude of current becomes double. The characteristic curve of the parallel combination of cells is represented below.

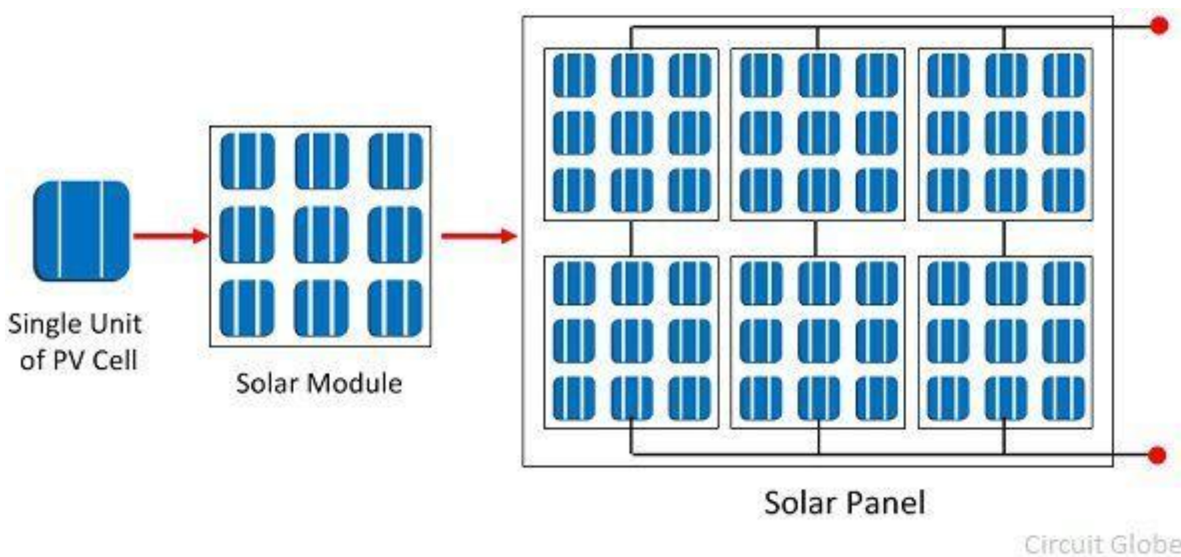


Series-Parallel Combination of PV cells

In the series-parallel combination of cells the magnitude of both the voltage and current increases. Thereby, the solar panels are made by using the series-parallel combination of the cells.



The solar module is constructed by connecting the single solar cells. And the combination of the solar modules together is known as the solar panel.

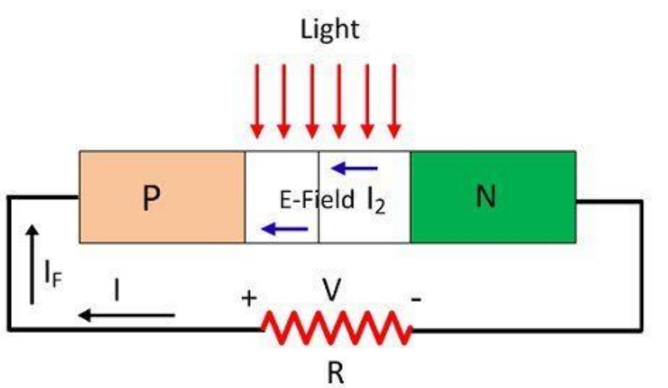


Working of PV cell

The light incident on the semiconductor material may be pass or reflected through it. The PV cell is made of the semiconductor material which is neither a complete conductor nor an insulator. This property of semiconductor material makes it more efficient for converting the light energy into electric energy.

When the semiconductor material absorbs light, the electrons of the material starts emitting. This happens because the light consists small energise particles called photons. When the electrons absorb the photons, they become energised and starts moving into the material. Because of the effect of an electric field, the particles move only in the one direction and develops current. The semiconductor materials have the metallic electrodes through which the current goes out of it.

Consider the figure below shows the PV cell made of silicon and the resistive load is connected across it. The PV cell consists the P and N-type layer of semiconductor material. These layers are joined together to form the PN junction.

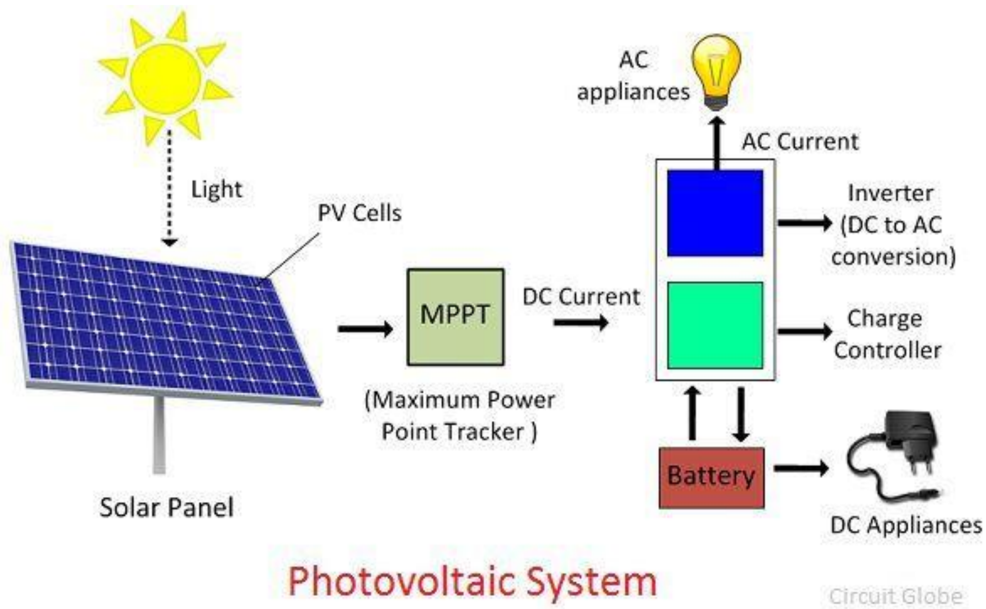


P-N Junction Solar Cell with Resistive Load

The junction is the interface between the p-type and n-type material. When the light fall on the junction the electrons starts moving from one region to another.

How Solar Cell Install on the Solar Power Plant?

Maximum power point tracker, inverter, charge controller and battery are the name of the apparatus used for converting the radiation into an electrical voltage.



Maximum Power Point Tracker – It's a special kind of digital tracker that follows the location of the sun. **The efficiency of the PV cell depends on the intensity of sunlight fall on it.** The power of the sun varies with the time because of the movement of the earth. So for absorbing the maximum light, the panel needs to be moved along with the sun. Thereby the maximum power point tracker is used with the solar panel.

Charge Controller – The charge controller regulates the voltage drawn from the panel. It also protects the battery from the overcharging or overvoltage.

Inverter – The inverter converts the direct current into the alternating current and vice versa. The conversion is essential because some of the appliances require ac supply for their work.

Advantages of Solar Cell

1. No pollution associated with it.
2. It must last for a long time.
3. No maintenance cost.

Disadvantages of Solar Cell

1. It has high cost of installation.
2. It has low efficiency.
3. During cloudy day, the energy cannot be produced and also at night we will not get solar energy.

Uses of Solar Generation Systems

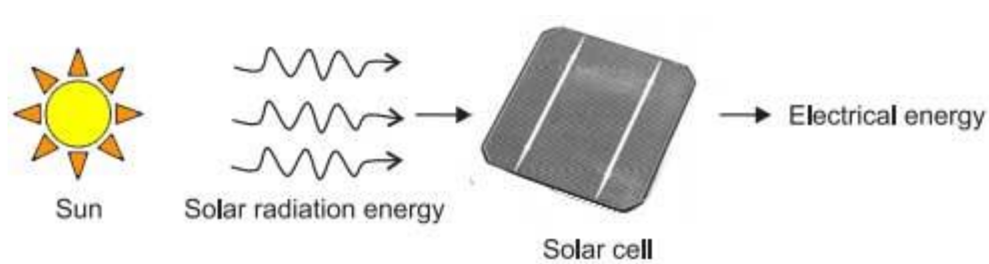
1. It may be used to charge batteries.
2. Used in light meters.
3. It is used to power calculators and wrist watches.
4. It can be used in spacecraft to provide electrical energy.

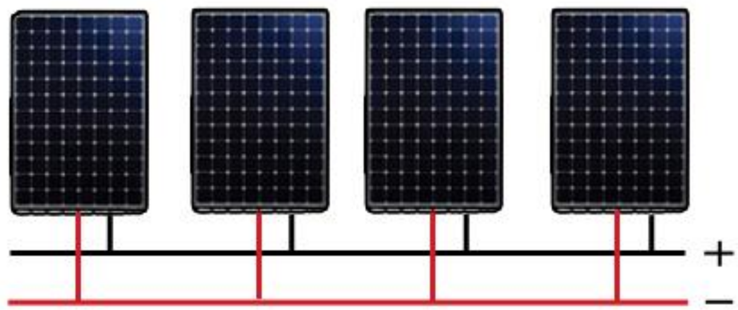
COMPONENTS OF A SOLAR ELECTRIC GENERATING SYSTEM

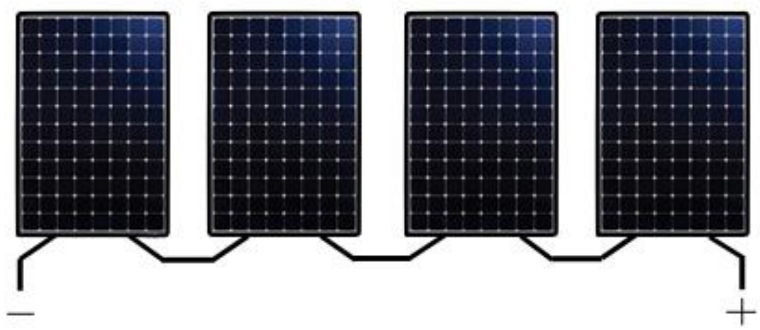
Solar Panels

The main part of a solar electric system is the **solar panel**. There are various types of **solar panel** available in the market. **Solar panels** are also known as **photovoltaic solar panels**. Solar panel or solar module is basically an array of series and parallel connected **solar cells**.

The potential difference developed across a solar cell is about 0.5 volt and hence desired number of such cells to be connected in series to achieve 14 to 18 volts to charge a standard battery of 12 volts. Solar panels are connected together to create a solar array. Multiple panels are connected together both in parallel and series to achieve higher current and higher voltage respectively.







Batteries

In grid-tie solar generation system, the solar modules are directly connected to an inverter, and are not connected directly to the load itself. The power collected from the solar panels is not constant, but rather it varies with the intensity of the sunlight shining on it. This is the reason why solar modules or panels do not feed any electrical equipment directly. Instead they feed an inverter whose output is synchronized with external grid supply.

Inverter takes care of the voltage level and frequency of the output power from the solar system it always maintains it with that of grid power level. As we get power from both solar panels and external grid power supply system, the voltage level and quality of power remain constant. As the stand-alone or grid fallback system is not connected with grid any variation of power level in the system can directly affects the performance of the electrical equipment fed from it.

So there must be some means to maintain the voltage level and power supply rate of the system. A battery bank connected parallel to this system takes care of that. Here the battery is charged by solar electricity and this battery then feeds a load directly or through an inverter. In this way variation of power quality due to variation of sunlight intensity can be avoided in solar power system instead an uninterrupted uniform power supply is maintained.

Normally Deep cycle lead acid batteries are used for this purpose. These batteries are typically designed to make capable of several charging and discharging during service. The battery sets available in the market are generally of either 6 volt or 12 volts. Hence number of such batteries can be connected in both series as well as parallel to get higher voltage and current rating of the battery system.

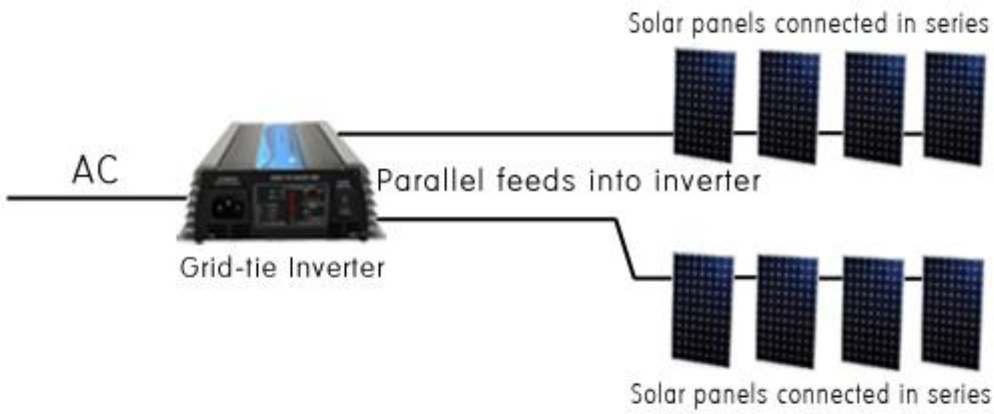
Controller

This is not desirable to overcharge and under discharge a lead acid battery. Both overcharging and under discharging can badly damage the battery system. To avoid these both situations a controller is required to attach with the system to maintain flow of current to and fro the batteries.

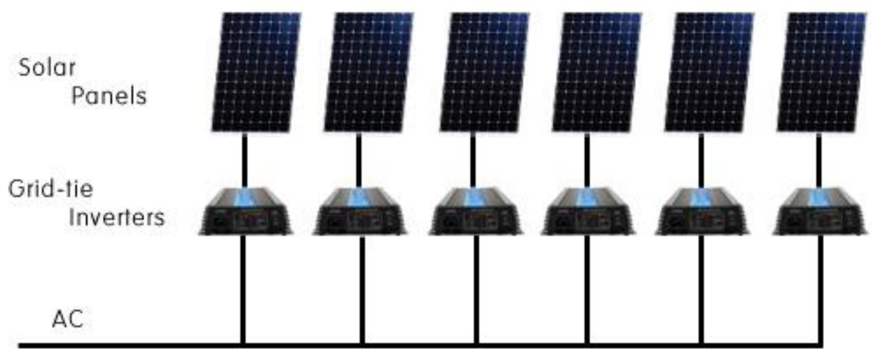
Inverter

It is obvious that the electricity produced in a solar panel is DC. Electricity we get from the grid supply is AC. So for running common equipment from grid as well as solar system, it is required to install an inverter to convert DC of solar system to AC of same level as grid supply.

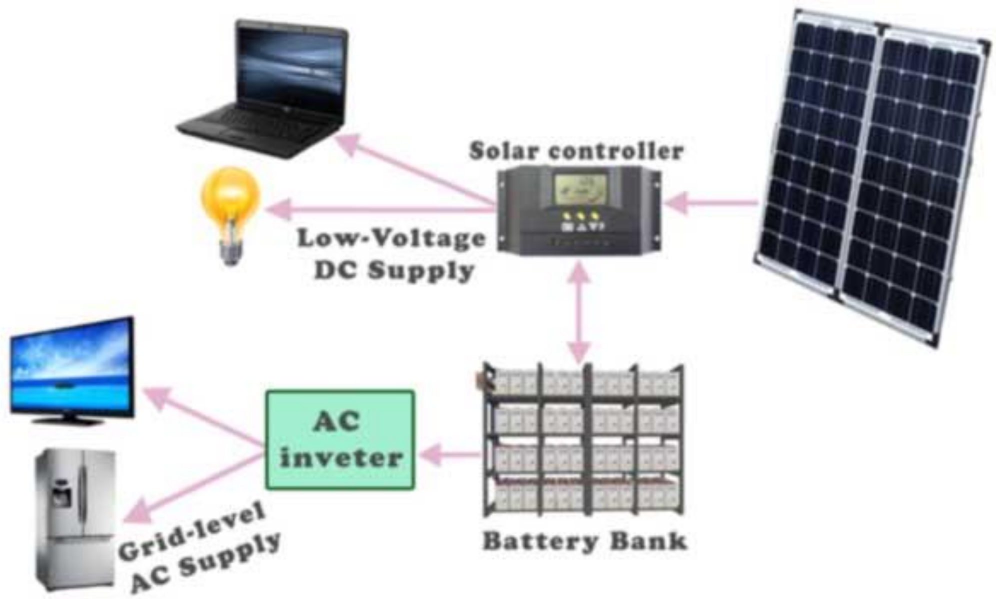
In off grid system the inverter is directly connected across the battery terminals so that DC coming from the batteries is first converted to AC then fed to the equipment. In grid tie system the solar panel is directly connected to inverter and this inverter then feeds the grid with same voltage and frequency power.



In modern grid tie system, each solar module is connected to grid through individual micro-inverter to achieve high voltage alternating current from each individual solar panel.



Components of Stand Alone Solar System

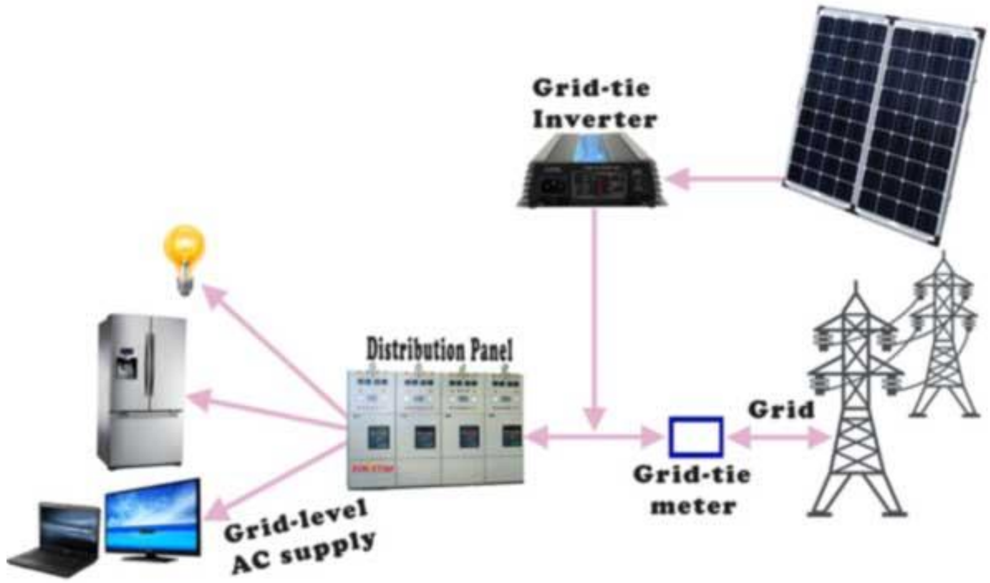


A basic block diagram of a stand-alone solar electric system is show above. Here the electric power produced in the solar panel is first supplied to the solar controller which in turn charges the battery bank or supplies directly to the low voltage DC equipment's such as laptops and LED lighting system. Normally the battery is fed from solar controller but it can also feed the solar controller when there is insufficient supply of power from solar panel.

In this way the supply is continued uniformly to the low voltage equipment's which are directly connected to the solar controller. In this scheme the battery bank terminals are also connected across an inverter. The inverter converts the stored DC power of the battery bank to high voltage AC for running larger electrical equipment's such as washing machines, larger televisions and kitchen appliances etc.

Components of Grid Tie Solar System

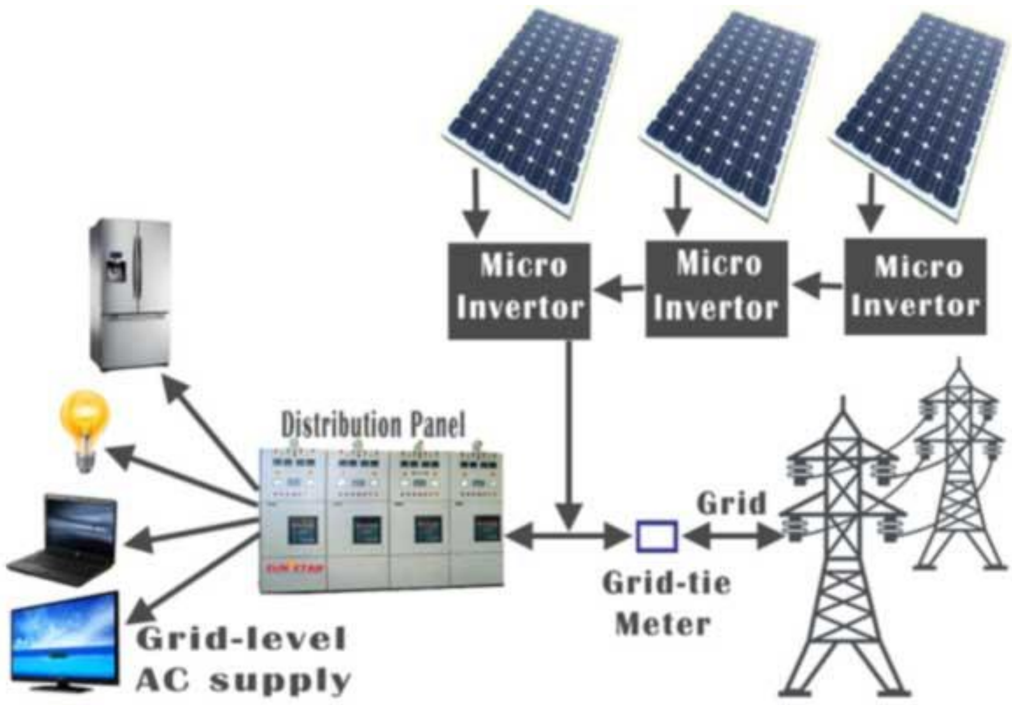
Grid tie solar systems are of two types one with single macro central inverter and other with multiple micro inverters. In the former type of solar system, the solar panels as well as grid supply are connected to a common central inverter called grid tie inverter as shown below.



The inverter here converts the DC of the solar panel to grid level AC and then feeds to the grid as well as the consumer's distribution panel depending upon the instantaneous demand of the systems. Here grid-tie inverter also monitors the power being supplied from the grid.

If it finds any power cut in the grid, it actuates switching system of the solar system to disconnect it from the grid to ensure no solar electricity can be fed back to the grid during power cut. There is on energy meter connected in the main grid supply line to record the energy export to the grid and energy import from the grid.

As we already told there is another type of grid-tie system where multiple micro-inverters are used. Here one micro inverter is connected for each individual solar module. The basic block diagram of this system is very similar to previous one except the micro inverters are connected together to produce desired high AC voltage.



In previous case the low direct voltage of solar panels is first converted to alternating voltage then it is transformed to high alternating voltage by transformation action in the inverter itself but in this case the individual alternating output voltage of micro inverters are added together to produce high alternating voltage.

MODULE II

BIO ENERGY ENGINEERING

INTRODUCTION TO BIO ENERGY

Biomass means living organisms and those that recently died. It does not include those organisms that are already converted to fossil fuel. In energy generation, it refers to waste plants that are utilized to generate energy by combustion.

The methods of conversion to bio-fuel are numerous and largely classified as **chemical, thermal** and **biochemical**. This is the oldest as well as the most widely spread source of renewable energy. It has a variety of conversion methods.

Direct combustion was traditionally practiced using wood fuel. Advanced processes such as **pyrolysis** (the process of making charcoal), fermentation and anaerobic digestion convert these sources to a denser and easy to transport forms such as oil and ethanol. Coal is a product of pyrolysis process, which strengthens the matter by burning it in the absence of Oxygen.

Bio-fuel is a term that refers to fuel derived from biomass. As mentioned before, biomass is any organic matter both living and dead and ranges from plants to organic wastes. In most cases, biomass rich in oil or sugar is ideal for energy production.

The term **bio-energy** refers to energy obtained from organisms either living or dead. This does not include fossil fuels. We could classify bio-fuel by their sources or according to generation.

Classification of Bio-Fuel by Source

- **Wood fuel** − Derived from trees, bushes, or shrubs. Examples of wood fuel include charcoal and wood.
- **Agro-fuels** − Obtained from farm product biomass such as dead crops or from other plant parts such as cereal. Agro-fuel is majorly derived from sugar and oil crops.
- **Municipal by-products** − Derived from waste collected from major towns. There are two categories of municipal waste. Solid waste bio-fuel is derived from direct combustion of solid waste from industries or commercial institutions. Liquid/gas waste bio-fuel is obtained from fermentation of the wastes collected.

Classification of Bio-Fuel by Generation

- **First generation** − Processed from sugar vegetable oil and animal fats pressed into oil for combustion in engines or fermented and processed into ethanol for the same purpose. The final products are oils, bio-diesel, alcohol, syngas, solid bio-fuel and biogas.
- **Second generation** − Derived from cellulose and waste (non-food). This waste is derived from stalks of crops and wood, bio-hydrogen, bio-alcohol, dimethyl formamide (DMF), wood diesel, mixed alcohol, and bio-dimethyl ether (DME).
- **Third generation** − Found in algae, believed to produce high yield of energy at low cost. The energy from algae is known as oil-gae.

The organic material is converted into usable form known as bio-energy. The materials used in the process of energy production are termed as feedstock.

To better understand biomass, we will explore the various sources first.

Biomass production refers to the increase in the amount of organic matter. It is the addition of organic matter in a given area or population. Biomass is considered renewable energy because it is replenished as plants and animals grow.

There are two forms of production −

- **Primary production** refers to the generation of energy by plants through photosynthesis. The excess energy generated is stored and adds up to the total biomass in the ecosystem. Primary production could be estimated from the total forest cover in a given year.

- **Secondary production** is the absorption of organic matter as body tissues by organisms. It includes ingestion by animals i.e. feeding, whether on other animals or on plants. It also involves decomposition of organic matter by microorganisms. Secondary production could be estimated as the total meat produced per year.

Though biomass could be measured as mass of organisms living and dead in a given environment, production is harder to estimate. It can only be estimated as the increase in volume though part of the additional biomass may have been replaced through natural processes.

Direct Combustion for Heat

Direct combustion for heat is the oldest method of biomass conversion to energy since the earliest civilizations. Thermochemical conversion (combustion) could be achieved in a number of ways using varied feedstock.

Standalone Combustion

Biomass based generators use diesel derived from vegetable oils to fuel diesel generators. The generators burn the organic diesel to produce energy to produce electricity.

- Combined heat and power plants are known to cogenerate electricity and useful heat energy. Ceramic industries utilize the heat in drying products such as clay tiles.

- Some power plants use biomass to heat water and produce steam for electricity generation. The biomass is burnt to produce enough heat to boil water.

- Municipal solid waste plants burn solid wastes to generate electricity. This type is prone to criticism since solid wastes mostly contain toxic gases from plastics and synthetic fibers.

Biomass Co-combustion

Apart from stand-alone combustion, biomass could be blended with other fossil fuels and burnt to generate energy. This is called co-firing.

- Biomass could be directly burnt as coal. This is referred to as direct co-combustion.
- In other cases, the biomass is first processed to gas and then converted to syngas.
- The third case is where fossil fuel is burnt in a different furnace and the energy produced is then used to preheat water in a steam power plant.

Types of Combustion

The various types of combustion are −

- **Fixed bed combustion** − this is a method where solid biomass is first cut into small pieces and then burnt on a flat fixed surface.
- **Moving bed combustion** − in this method, a grate is set to constantly and evenly move leaving ash behind. The fuel burns in combustion levels.
- **Fluid-bed combustion** − Fuel is boiled under high pressure mixed with sand. The sand serves to distribute the heat evenly.
- **Burner combustion** − in this method, wood dust and fine dust are placed in a burner similar to that of liquid fuel.
- **Rotary furnace combustion** − A kiln furnace is used to burn organic matter with high moisture content. Such waste as food residue or other moist farm waste is burnt this way.

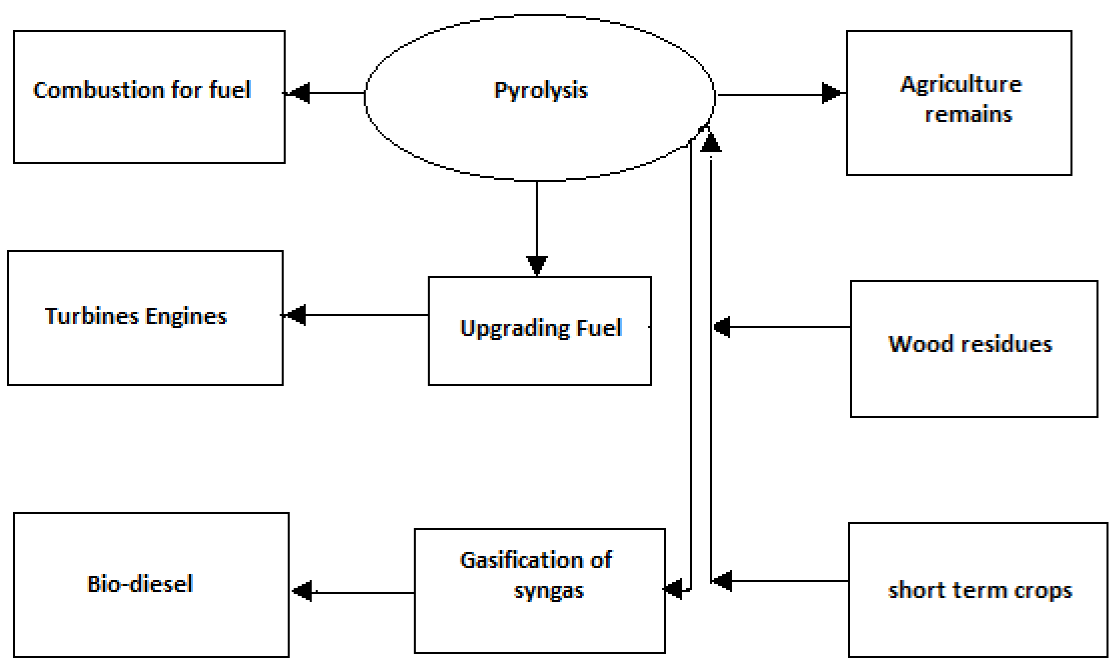
Pyrolysis

Pyrolysis is another form of processing bio-fuels by burning under very high temperatures without oxygen, which could cause complete combustion. This causes irreversible physical and chemical changes. The absence of oxidation or halogenations processes results in a very dense bio-fuel that could be used in combustion, co-combustion or converted to gas.

- **Slow pyrolysis** occurs at about 400^oC. It is the process of making solid charcoal.
- **Fast pyrolysis** occurs between 450^oC to 600^oC and results in organic gas, pyrolysis vapor, and charcoal. The vapor is processed by condensation to liquid form as biooil. This must be done within 1 second to prevent further reaction. The resultant liquid is dark brown liquid denser than wood biomass and has equal content in terms of energy.

Bio-oil has a number of advantages. It is easier to transport, burn, and store. Many kinds of feedstock can be processed through pyrolysis to produce bio-oil.

The diagram given below explains the process in converting energy in to a usable form from bio-fuels through Pyrolysis.



Alcoholic Fermentation

Alcoholic fermentation is the process that converts sugars into cellulose. The process results in ethanol and carbon dioxide as the by-products. This process is considered anaerobic since it takes place in the absence of oxygen. Apart from bread baking and manufacturing alcoholic beverages, this process produces alcoholic fuel.

Sugarcane is the main feedstock for this process especially in dry environments. Corn or sugar bits are used in temperate areas.

Application of Products

The products have the following applications −

- **Acetone** is a product used for production of food additives, dissolving glue, thinning of paint, grease removers and in cosmetic products.
- **Hydrogen** is used as a cooling agent in power industry. It is also used in hydrogen cells for energy production.
- **Butanol** provides better fuel than ethanol. It is also used as an ingredient in paint, cosmetic products, resins, dyes, polymer extractions and in the manufacture of synthetic fiber.
- **Ethanol** is used as fuel, paint component, and an additive in antiseptics. It is also used in alcoholic beverages.

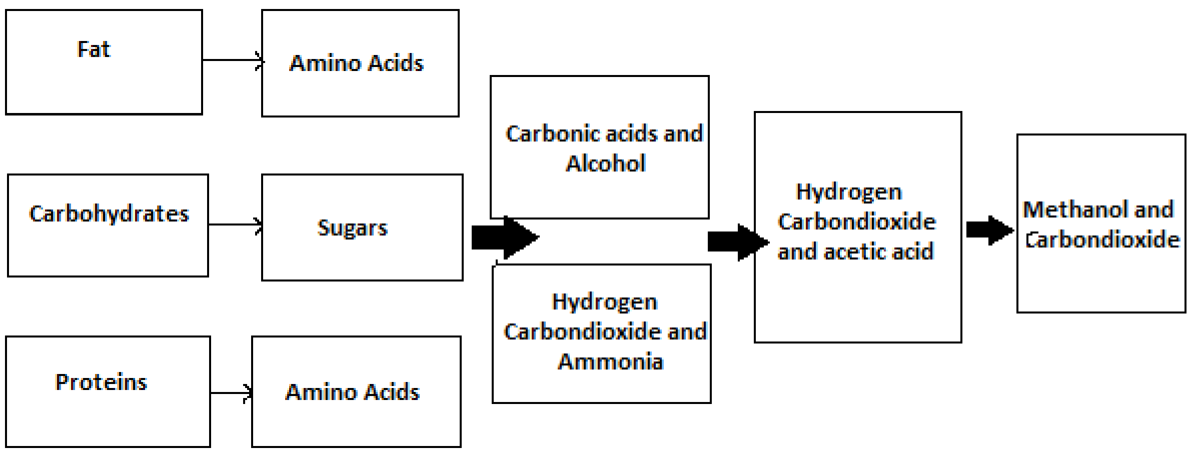
Anaerobic Digestion of Biogas

Anaerobic digestion is the biological process by which organic matter is broken down to produce biogas in the absence of Oxygen. Microorganisms such as Acidogenetic bacteria and acetogens convert the biodegradable matter to biogas. Apart from being a source of energy, it is also a waste deposition method and environmental conservation technique.

The step-by-step process is explained below −

- **Step 1** − Breakdown of organic matter to sizable molecules for conversion. This process is known as hydrolysis.

- **Step 2** − Acidogens act on the decomposed matter converting them into volatile fatty acids (VFAs) alongside ammonia, CO2 and hydrogen sulfide. The process is called acidogenesis.
- **Step 3** − The Volatile Fatty Acids (VFAs) are further broken down into acetic acid, carbon dioxide and hydrogen.
- **Step 4** − The final stage is the combination of emissions above to produce methanol, carbon dioxide, and water.



BIOMASS COMPOSITION AND PROPERTIES

What is biomass?

Biomass is material that is derived from living or recently living biological organisms. In the energy context it is often used to refer to plant material, however by-products and waste from livestock farming, food processing and preparation and domestic organic waste, can all form sources of biomass. Biomass is carbon based and is composed of a mixture of organic molecules containing hydrogen, usually including atoms of oxygen, often nitrogen and also small quantities of other atoms, including alkali, alkaline earth and heavy metals. Plants use the light energy from the sun to convert water and carbon dioxide to sugars that can be stored, through a process called photosynthesis. Researchers study how the sugars in the biomass can be converted to more usable forms of energy like electricity and fuels. Some plants, like sugar cane and sugar beets, store energy as simple sugars. Other plants store the energy as more complex sugars called starches. These plants include grains like corn. All of these are also used for food.

Another type of plant matter, called cellulosic biomass, is made up of very complex sugar polymers, and is not generally used as a food source. Cellulosic feedstocks under consideration for biofuels include:

- Agricultural residues (leftover material from crops, such as the stalks, leaves, and husks of corn plants)
- Forestry wastes (chips and sawdust from lumber mills, dead trees, and tree branches)
- Municipal solid waste (household garbage and paper products)
- Food processing and other industrial wastes (black liquor, a paper manufacturing by-product)
- Energy crops (fast-growing trees and grasses) developed just for this purpose

The main components of these types of biomass are:

- **Cellulose** is the most common form of carbon in biomass, accounting for 40%-60% by weight of the biomass, depending on the biomass source. It is a complex sugar polymer, or polysaccharide, made from the six-carbon sugar, glucose. Its crystalline structure makes it resistant to hydrolysis, the chemical reaction that releases simple, fermentable sugars from a polysaccharide.
- **Hemicellulose** is also a major source of carbon in biomass, at levels of between 20% and 40% by weight. It is a complex polysaccharide made from a variety of fiveand six-carbon sugars. It is relatively easy to hydrolyze into simple sugars but the sugars can be difficult to ferment.
- **Lignin** is a complex polymer, which provides structural integrity in plants. It makes up 10% to 24% by weight of biomass. It remains as residual material after the sugars in the biomass have been converted. It contains a lot of energy and can be burned to produce steam and electricity for biochemical biomass processing.

Why use biomass?

Biomass is an attractive energy source for a number of reasons.

- The use of biomass energy has the potential to greatly reduce greenhouse gas emissions. Burning biomass releases about the same amount of carbon dioxide as burning fossil fuels. However, fossil fuels release carbon dioxide captured by photosynthesis millions of years ago. Biomass, on the other hand, releases carbon dioxide that is largely balanced by the carbon dioxide captured in its own growth (depending how much energy was used to grow, harvest, and process the fuel).
- The use of biomass can reduce dependence on foreign oil because biofuels are the only renewable liquid transportation fuels available.
- Biomass energy supports U.S. agricultural and forest-product industries. The main biomass feedstocks for power are paper mill residue, lumber mill scrap, and municipal waste. For biomass fuels, the most common feedstocks used today are corn grain (for ethanol) and soybeans (for biodiesel). In the near future, agricultural. residues such as corn stover (the stalks, leaves, and husks of the plant) and wheat straw will also be used. Long-term plans include growing and using dedicated energy crops, such as fast-growing trees and grasses, and algae. These feedstocks can grow sustainably on land that will not support intensive food crops.

Biomass has successfully been used before to supply energy and has the potential to do so again.

- Up until the 1860s, the U.S. used biomass (wood) for nearly 91% of all energy consumption.
- 14% of the world still utilizes biomass for energy.
- In a recent DOE study, a full 73% of all energy consumed by US manufacturing was through boilers and burners, principally powered by natural gas or fuel oil, but highly adaptable to solid fuel usage.

Biomass Challenges

There are several challenges associated with using biomass for energy, especially liquid transportation fuels.

- **Biomass is seasonal;** most energy and feedstock demands are continuous.
- **Biomass is very heterogeneous and complex**; properties of biomass can vary with the species of plant, the location in which it was grown, the growing conditions, the harvest and storage conditions, etc. The ability to consistently and accurately measure biomass properties is therefore critical to designing bioprocessing operations.
- **Biomass has a relatively low energy density,** meaning that it takes a lot more biomass to supply the same amount of energy as a traditional hydrocarbon fuel.
- **The market for bio-based energy and other bio-based products** (i.e. suppliers, buyers, distributors, prices, demand) is relatively undeveloped.

Heating Value

The heating value, in units of MJ/kg or BTU/lb or cal/g, is one of the most important characteristics of a fuel because it indicates the total amount of energy that is available in the fuel. Heating value is mostly a function of a fuel's chemical composition and can be expressed in two ways: the higher heating value (HHV) or the lower heating value (LHV). HHV is the total amount of heat energy that is available in the fuel, including the energy contained in the water vapor in the exhaust gases. LHV is the same as HHV except that it does not include the energy embodied in the water vapor. Generally, the HHV is the appropriate value to use for biomass combustion, although some manufacturers may utilize the LHV instead, which can lead to confusion.

The HHV for coal ranges from 20 to 30 MJ/kg (8600-12900 Btu/lb). Nearly all kinds of biomass feedstocks destined for combustion fall in the "as-received" (not oven dry) HHV range of 15-19 MJ/kg (6450-8200 Btu/lb) with 15-17 MJ/kg (6450-7300 Btu/lb) for most agricultural residues and 18-19 MJ/kg (7750-8200 Btu/lb) for most woody materials.

Moisture Content

Moisture content is one of the easier biomass properties to measure and can make the difference between a good and a bad fuel. High moisture fuels burn less readily and provide less useful heat per unit mass; this is because water itself provides no energy value and much of the energy in the fuel is used up to heat and vaporize water. Fresh, “green” wood is often about half water; many leafy crops are primarily water. On the other hand, extremely dry fuel can cause dust problems, leading to equipment fouling and potential explosion hazards. Moisture content can be calculated on two bases: wet or dry. In wet basis calculations, the moisture content is equal to the mass of water in the fuel divided by the total mass of the fuel. In dry basis calculations, the moisture content is equal to the mass of water in the fuel divided by the mass of the dry portion of the fuel. It is important to know which type of calculation is being used, as the two values can be quite different. For example, a 50% wet basis moisture level is the same as a 100% dry basis moisture level. Air-dried biomass typically has about 15-20% moisture, whereas the moisture content for oven-dried biomass is around 0%. Moisture content is also an important characteristic of coals, varying in the range 2-30%. The practical maximum moisture level for combusting fuel is about 60% (wet basis), although most commercial equipment operates with fuels that only have up to about 40 % moisture.

Composition of biomass

In addition to heating value and moisture content, three other biomass properties are significant to biomass’ performance as a fuel:

(1) Ash content,

(2) Susceptibility to slagging and fouling, and

(3) Volatiles content.

Ash content is the mass fraction of biomass composed of incombustible mineral material. Grasses, bark, and field crop residues typically have much higher ash contents than wood. Systems that are designed to combust wood can be overwhelmed by the volume of ash if other biofuels are used.

Slagging and fouling are problems that occur if ash begins to melt during combustion, forming deposits on combustor surfaces (fouling) or leaving hard chunks of glassy material in the bottom of the combustion chamber (slag, aka “clinkers”).

Certain mineral components in biomass fuels, primarily silica, potassium, and chlorine, can cause these problems to occur at lower temperatures than normal. Many studies have observed that the high mineral content in grasses and field crops can contribute to fouling and clinkering—a potentially expensive problem for a combustion system. The timing of harvest can affect this property, with late harvested crops having noticeably lower ash content (Adler et al., 2006). Dirt contamination also adds to the mineral content and associated slagging and fouling problems, so it is important that biomass feedstock be as "clean" as possible. Slagging and fouling is minimized by keeping combustion temperatures low. Alternately, some biomass combustion equipment is designed to encourage the formation of clinkers but is able to dispose of the hardened ash in an effective manner. Table 1shows a "slagging index" and a "fouling index" for several fuels, two measures that give some indication of the tendency of a fuel to form slag or foul a boiler. Values lower than 0.6 are preferable. These indices, however, were developed for coal combustion and their significance for biomass fuels is questionable. Treat these values with caution.

The volatiles content in a fuel is a lesser-known property that refers to the fraction of the fuel that will readily volatilize (turn to gas) when heated to a high temperature. Fuels with "high volatiles" will tend to vaporize before combusting ("flaming combustion"), whereas fuels with low volatiles will burn primarily as glowing "char." This affects the performance of the combustion chamber and should be taken into account when designing a combustor.

Table Examples of ash, slagging, fouling, and volatiles.

Fuel	Percent ash content	Slagging index	Fouling index	Percent volatiles
Wood, clean and dry	0.3	0.05	7	82
Bark, dry	1.2	5.6	34	70
Switchgrass	5.2	0.06	4.2	76
Corn stover	5.6	0.04	8.2	75
Coal	12	0.08	0.13	35

Fuel Size and Density

The particle size and density of biomass fuels are also important as they affect the burning characteristics, namely the rate of heating and drying during the combustion process. Fuel particle size also dictates the type of handling equipment required. The wrong size fuel will negatively impact combustion process efficiency and may cause jamming or damage to the handling equipment. Smaller-sized fuel is more common for commercial-scale systems because smaller fuel is easier to use in automatic feed systems and allows for finer control of the burn rate by controlling the rate at which fuel is added to the combustion chamber. Fuel particle size and density are probably the most overlooked factors affecting fuel performance and should be given careful consideration when selecting a fuel type. Bulk density is the mass of a material divided by the volume it occupies. Bulk density of granular materials is dependent on the manner in which it is handled. For example, freely settled material has a lower bulk density than tapped or compacted materials. Table lists the size and bulk density of some common biomass fuels.

Angle of Repose

Angle of repose is the maximum angle that bulk granular materials will form when poured onto a horizontal surface due to particle size and frictional and cohesive forces between individual particles. The angle of repose of materials is important to the design of storage structures and material handling equipment.

Table Typical size and density of biomass fuels.

Fuel	Length (m)	Bulk density (kg/m^3)
Sawdust	0.0003–0.002	300
Chopped straw	0.005–0.025	60
Green wood chips	0.025–0.075	500
Wood pellets	0.006–0.008	600
Biomass briquettes	0.025–0.010	600
Cordwood	0.3–0.5	400

BIOMASS VS FOSSIL FUELS

The bulk density (and resulting energy density) of most biomass feedstocks is generally low, even after biomass densification: about 10- 40% of the bulk density of most fossil fuels, although liquid biofuels have comparable bulk densities.

Most biomass materials are easier to gasify than coal, because biomass is more reactive and has higher ignition stability. This characteristic also makes biomass easier to process thermochemically into higher-value fuels such as methanol or hydrogen. Biomass ash content is typically lower than for most coals, and sulphur content is much lower than for many fossil fuels. Unlike coal ash, which may contain toxic metals and other trace contaminants, biomass ash may be used as a soil amendment to help replenish nutrients removed by harvest.

Among the liquid biomass fuels, biodiesel (vegetable oil ester) is similarity to petroleumderived diesel fuel, apart from its negligible sulfur and ash content. Bioethanol has only about 70% the heating value of petroleum, but its sulfur and ash contents are also very low. Both of these liquid fuels have lower vapor pressure and flammability than their petroleum counterparts, an advantage in some cases (e.g. use in confined spaces such as mines) but a disadvantage in others (e.g. engine starting at cold temperatures).

BIOMASS PROPERTIES BIOMASS COMPOSITION, CHEMICAL CHARACTERISTICS AND PHYSICAL CHARACERISTICS.

		COMPOSITION		
		cellulose (%)	hemi-cellulose (%)	lignin (%)
Bioenergy Feedstocks	corn stover	35	28	16-21
	sweet sorghum	27	25	11
	sugarcane bagasse	32-48	19-24	23-32
	sugarcane leaves			
	hardwood	45	30	20
	softwood	42	21	26
	hybrid poplar	42-56	18-25	21-23
	bamboo	41-49	24-28	24-26
	switchgrass	44-51	42-50?	13-20
	miscanthus	44	24	17
	Arundo donax	31	30	21
Liquid Biofuels	bioethanol	N/A	N/A	N/A
	biodiesel	N/A	N/A	N/A
Fossil Fuels	Coal (low rank; lignite/sub-bituminous)	N/A	N/A	N/A
	Coal (high rank; bituminous/anthracite)	N/A	N/A	N/A
	Oil (typical distillate)	N/A	N/A	N/A

		CHEMICAL CHARACTERISTICS				
		heating value (gross, unless specified; GJ/t)	ash (%)	sulfur (%)	potassium (%)	Ash melting temperature [some ash sintering observed] (C)
Bioenergy Feedstocks	corn stover	17.6	5.6			
	sweet sorghum	15.4	5.5			
	sugarcane bagasse	18.1	3.2-5.5	0.10-0.15	0.73-0.97	
	sugarcane leaves	17.4	7.7			
	hardwood	20.5	0.45	0.009	0.04	[900]
	softwood	19.6	0.3	0.01		
	hybrid poplar	19.0	0.5-1.5	0.03	0.3	1350
	bamboo	18.5-19.4	0.8-2.5	0.03-0.05	0.15-0.50	
	switchgrass	18.3	4.5-5.8	0.12		1016
	miscanthus	17.1-19.4	1.5-4.5	0.1	0.37-1.12	1090 [600]
	Arundo donax	17.1	5-6	0.07		
Liquid Biofuels	bioethanol	28		<0.01		N/A
	biodiesel	40	<0.02	<0.05	<0.0001	N/A
Fossil Fuels	Coal (low rank; lignite/sub-bituminous)	15-19	5-20	1.0-3.0	0.02-0.3	~1300
	Coal (high rank; bituminous/anthracite)	27-30	1-10	0.5-1.5	0.06-0.15	~1300
	Oil (typical distillate)	42-45	0.5-1.5	0.2-1.2		N/A

		PHYSICAL CHARACTERISTICS		
		Cellulose fiber length (mm)	Chopped density at harvest (kg/m^3)	Baled density [compacted bales] (kg/m^3)
Bioenergy Feedstocks	corn stover	1.5		
	sweet sorghum			
	sugarcane bagasse	1.7	50-75	
	sugarcane leaves		25-40	
	hardwood	1.2		
	softwood			
	hybrid poplar	1-1.4	150 (chips)	
	bamboo	1.5-3.2		
	switchgrass		108	105-133
	miscanthus		70-100	130-150 [300]
	Arundo donax	1.2		
(typical bulk densities or range given below)				
Liquid Biofuels	bioethanol	N/A	N/A	790
	biodiesel	N/A	N/A	875
Fossil Fuels	Coal (low rank; lignite/sub-bituminous)	N/A	N/A	700
	Coal (high rank; bituminous/anthracite)	N/A	N/A	850
	Oil (typical distillate)	N/A	N/A	700-900

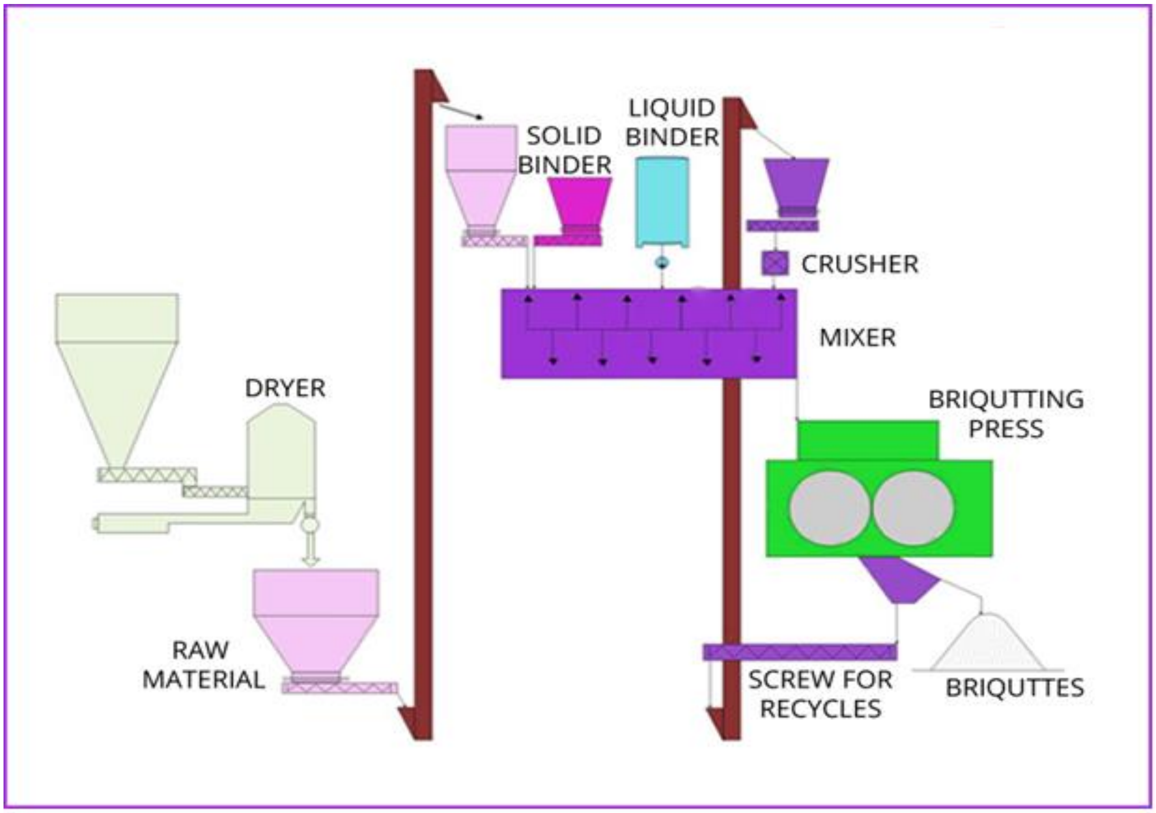
BIOMASS SIZE REDUCTION TECHNIQUES

BRIQUETTING & DRYING

Briquetting is a process of compacting, destroying the elasticity of the natural fibers. During this process biomass is compressed under high pressure and high temperature. The process of briquetting is completely eco-friendly.

Testing: In the initial stage of process, the quality of raw material is tested during different stages. All the components consist of saw dust, ground nut shells, castor seed shells and other material upto size 25mm are used. Testing is done for the chemical composition to decide their suitability and to select a proper mix.

Crushing: For the Proper working of biomass briquette press and drying machine in the biomass briquetting plant, size of surplus material plays a vital role. In this stage, two types of machine are suitable depending upon the size sawdust or biomass grain for following drying machine and biomass briquette press.



Saw Dust Drying Machine: At the time of inserting raw material into the hopper of dryer, it creates hot air which is mixed with wet sawdust and then sucked into the pipes by the exhaust blower(fan) , flowing and then allowed to pass the curving pipes and drying chamber of dryer, where the wet sawdust is dried and than it is discharged from the outlet with air lock Biomass Briquette Machine: The dehydrated Biomass material containing approx. 15% of moisture is suitable for briquetting. If the material contains high amount of moisture it has to be dried through flash dryer or sun before usage.

Final Briquettes:

At last we get briquettes in the shape of logs or pellets, which are enforced through tracks for proper shaping, by cooling them under pressure.

Packing: Cooled briquettes are cut and packed in bags or stored in bulk for dispatch.

BRIQUETTING PROCESS

The idea of Briquetting is using raw materials that are not usable due to a lack of density, compressing them into a solid fuel of a convenient shape that can be burned like wood or charcoal. The briquettes have improved physical and combustion characteristics than the initial waste. Briquettes will develop combustion efficiency using the existing traditional furnaces. In addition Briquettes to killing all insects and diseases as well as reducing the destructive fires risk in the countryside.

Steps used for a Briquetting process:

The process of Briquetting consists of the following steps:

- Gathering biomass waste material
- Crushing
- Compressing to form a briquette
- Drying the briquette

In the Briquetting process, the materials are first crushed into a very small size so that they can be compressed properly and burn easily. Special crushing machine is obtainable in the market to crush the raw materials. The briquette is highly preferred in the locations where fuel is hard to find and is costly. Thus at such places, Briquetting can become the best choice for getting fuel at a cheap price and easy way. The major advantage in a Briquetting plant is that it does not require any binder to bind the materials together to form a briquette. Thus it is also called as **binder-less technology.**

The briquettes are chosen over coal and other nonrenewable fuel that are hard to get and generate. The advantage of Briquetting is the high calorific valve helpful in easy ignition. Also, other main factors for Briquetting are low production cost, waste material management and conversion of waste to revenue.

Some facts about Briquette:

- A briquette is a compressed block of coal dust or other biomass material such as charcoal, sawdust, or paper used for fuel and to begin a fire. The term derives from the French word briquette meaning brick.
- Briquetting is the procedure of creating briquettes. A briquette is mainly a block of compressed biomass waste get from natural materials like agricultural waste, forestry waste, coal pieces, etc. These briquettes perform as the best substitute for nonrenewable fuel that is nature-friendly. This briquette poses no harmful effect on the environment and is atmosphere friendly. The major use of these briquettes is as a substitute to fuel, coal, cooking and even in boilers.
- Briquettes can be produced with a density of 1.2 g/cm^3 from loose biomass Briquettes of bulk density 0.1 to 0.2 g / cm^3 These can be burnt clean and therefore are eco-friendly arid those advantages that are associated with the use of biomass are present in the briquettes.
- India is the only country where the Briquetting sector is growing regularly in spite of some failures. As an effect of a few successes and Indian Renewable Energy Development Agency (IREDA) promotional efforts, a number of entrepreneurs are confidently investing in biomass briquette. These entrepreneurs are making strenuous

efforts to improve both the production process and the technology.

- Briquettes are flammable blocks of matter which can be used as fuel. They are prepared from extruded or compressed shredded combustible materials. A binding agent like starch can be necessary to hold the materials together, though pressure may at times be enough.
- Briquetting or pelletizing is the process to develop the characteristics of biomass as a renewable energy resource by densification. Densification means less volume required for the same amount of energy output.

Benefits of Briquetting:

Major benefits from the utilization of briquettes as fuel are;

More efficient: Along with the compactness of the briquettes is the increase in heating charge. Briquettes can moderately produce more intense heat than other fuel. They have a higher practical thermal importance and much lower ash content (2-10% compared to 20-40% in coal). In fact, they are 40% more capable, as well as hotter and longer lasting than firewood. This better efficiency can be attributed to their low moisture & density.

Concentrated: Since briquettes are formed from compressing combustible materials, they are denser, harder, and more compact. They have a very high specific density (1200kg/m3) and bulk density (800kg/m3) compared to 60 to 180 kg/m3 of loose biomass. Hence, they offer a more concentrated form of energy than firewood or charcoal.

Slow-burning: The compression procedure allows the briquettes to burn for a lot longer than if it was loose in its original condition.

Easy to make: There are currently commercial briquettes sold in the market. However, ordinary households can create briquettes. You must have a stock of combustible matter, a binder, and a molder to shape the briquettes.

Smokeless: This is a unique property of briquettes. Using them generate no smoke, soot, or carbon deposits. Depending on the base material, they create no or little fly ash.

Easily transported: Compacting biomass waste into briquettes reduces the volume by ten times, making it much easier to store and transport than loose biomass waste. Considering their shape, size, and density, briquettes are superb for long-distance transport.

Easily stored: The size and shape of briquettes create them easily be stored. We can readily pile them in some heaps as of their fun shapes like cubical, spherical shape, cylindrical, or rectangular blocks. They are likewise very clean to handle and be packed into bags.

Cheaper: Since briquettes can be domestically prepared from plants and animal wastes, they are consequently less expensive to produce, and thereby sold at lower prices.

APPLICATIONS OF BRIQUETTES

The applications of Briquettes in India are given below;

Domestic use: Many households generally use briquettes for cooking, space, and water heating purposes.

Hospitality: Hospitals used Briquettes for space and water heating, and cooking applications.

Ceramic production: Many ceramic industries use Briquettes for tile creation, brick kilns, and pot firing.

Textiles: Textile industries use high-quality Briquettes for bleaching and drying functions.

Commercial and institutional catering: Commercial firms use these Briquettes for grilling, cooking, and water heating.

Food Processing Industries: Food processing industries use Briquettes in the drying, bakeries, distilleries, canteens, and restaurants.

Industrial Boilers: Industrial boilers use high-density Briquettes for the steam generation and heat generation.

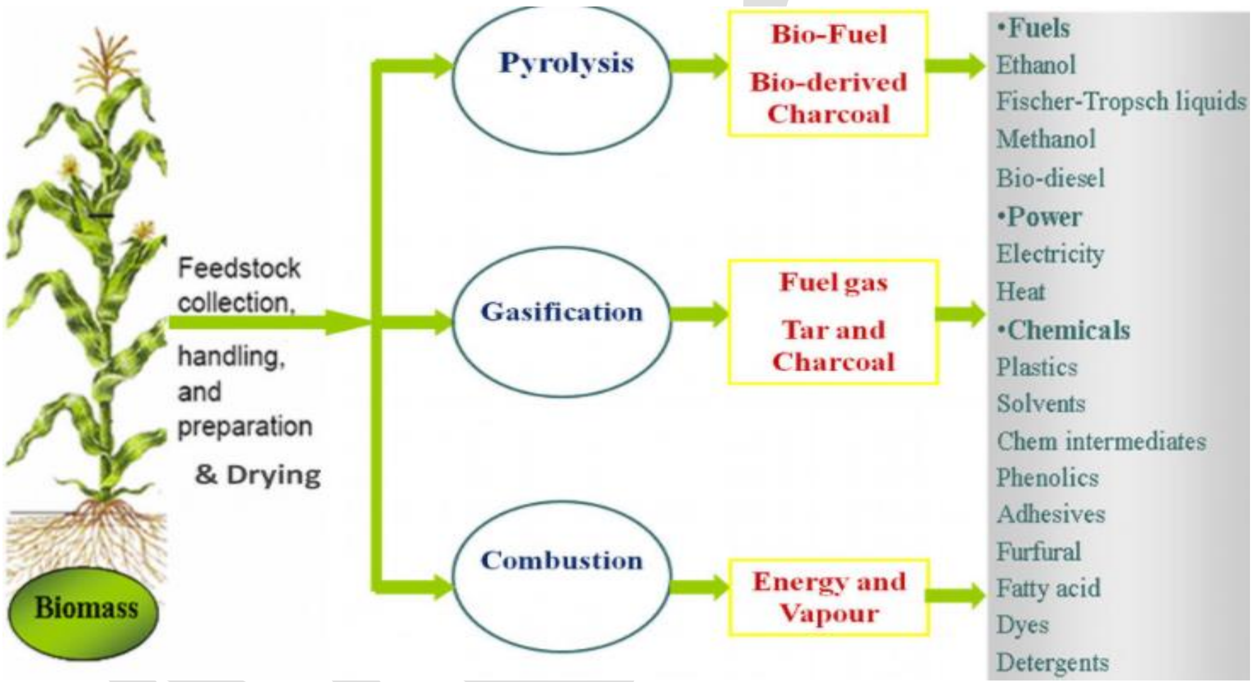
Poultry: Briquettes generated out of Briquette Machines are used by the poultry for the heating of chicks and incubation purposes.

Agriculture-based Industries: Agro-based industries use Briquettes for tea drying, tobacco curing, and oil milling, etc.

Gasification: Many industries use Briquettes as the fuel for the gasifiers to produce electricity.

DRYING OF BIOMASS

Drying biomass Through a drying process, moisture can be largely removed from biomass. The result is a reduction in the weight of the biomass. This leads to a reduction of the processing costs, as well as of the costs for storage and transport.



WHAT IS PYROLYSIS?

Pyrolysis can be defined as the process of subjecting substances to highly elevated temperatures in relatively inert atmospheres in order to facilitate their thermal decomposition. It is important to note that the process of pyrolysis brings about a chemical change in the substance subjected to it (the chemical compositions of the initial reactant feedstock and the final product are different). The term ‘pyrolysis’ has Greek roots and can be roughly translated as “fire separating”. Generally, substances that are subjected to pyrolysis undergo a chemical decomposition reaction and break down into multiple product compounds.

The process of pyrolysis is widely used to break down organic substances. For example, the charring of wood (or the incomplete combustion of wood) that results in the formation of charcoal involves the process of pyrolysis. Typically, the pyrolysis of an organic substance will produce multiple volatile products and will also leave behind a solid residue which is often highly enriched with carbon. It can be noted that extreme pyrolysis, which often leaves only carbon as a residue, is commonly known as carbonization. It can also be noted that pyrolysis is widely considered as the initial step for other related processes such as combustion and gasification.

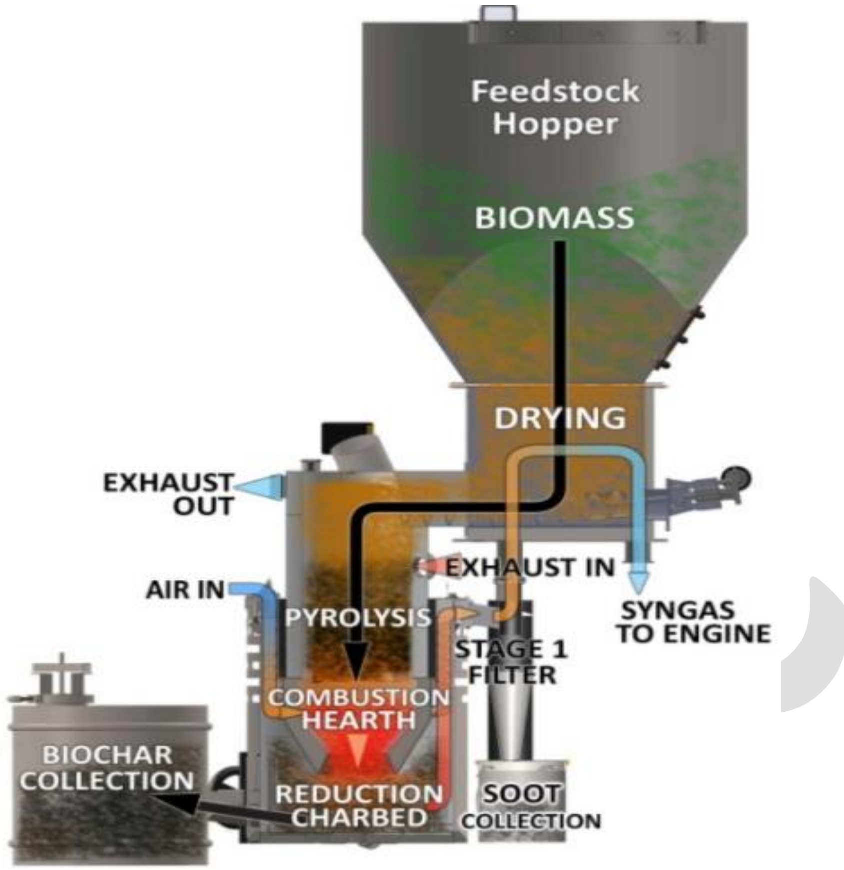
The chemical industry makes extensive use of the process of pyrolysis.

One of the most important applications of this process is in the production of ethylene and other important carbon compounds from coal and petroleum. Furthermore, it can be noted that these compounds can also be extracted from certain organic matter such as wood. Coke can be obtained from coal (along with a wide spectrum of different compounds) via the process of pyrolysis.

GASIFICATION PROCESS

Gasification is most simply thought of as choked combustion or incomplete combustion. It is burning solid fuels like wood or coal without enough air to complete combustion, so the output gas still has combustion potential. The unburned gas is then piped away to burn elsewhere as needed.

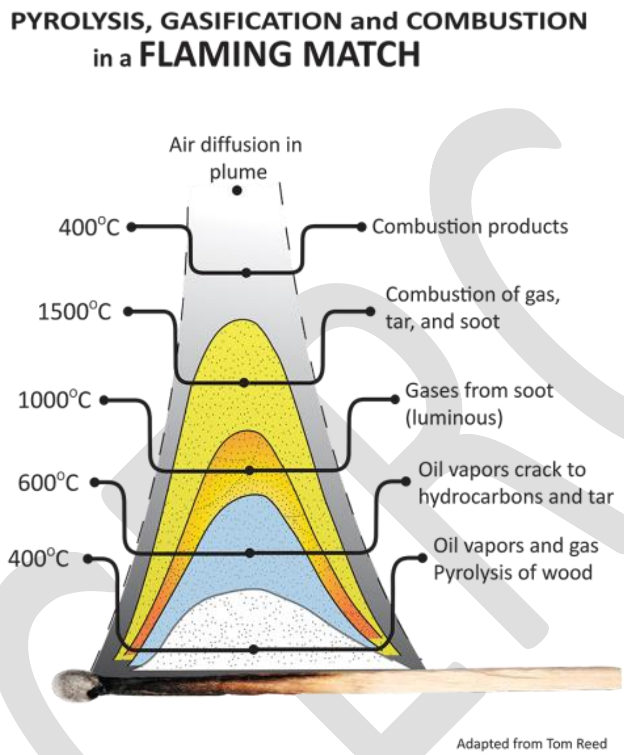
Gas produced by this method goes by a variety of names: *wood gas, syngas, producer gas, town gas, generator gas*, and others. It's sometimes also called *biogas*, though biogas more typically refers to gas produced via microbes in anaerobic digestion. In the context of biomass gasification using air-aspirated gasifiers, the term *producer gas* is the term we will be using, since the other terms have implications that do not necessarily apply to the gas produced by our gasifiers.



COMBUSTION & DRYING

Combustion is the only net exothermic process of the Five Processes of Gasification; ultimately, all of the heat that drives drying, pyrolysis, and reduction comes either directly from combustion, or is recovered indirectly from combustion by heat exchange processes in a gasifier. Combustion can be fueled by either the tar gasses or char from Pyrolysis. Different reactor types use one or the other or both. In a downdraft gasifier, we are trying to burn the tar gasses from pyrolysis to generate heat to run reduction, as well as the CO_2 and H_2O to reduce in reduction. The goal in combustion in a downdraft is to get good mixing and high temps so that all the tars are either burned or cracked, and thus will not be present in the outgoing gas. The char bed and reduction contribute a relatively little to the conversion of messy tars to useful fuel gasses. Solving the tar problem is mostly an issue of tar cracking in the combustion zone.

Drying is what removes the moisture in the biomass before it enters Pyrolysis. All the moisture needs to be (or will be) removed from the fuel before any above 100°C processes happen. All of the water in the biomass will get vaporized out of the fuel at some point in the higher temp processes. Where and how this happens is one of the major issues that has to be solved for successful gasification. High moisture content fuel, and/or poor handling of the moisture internally, is one of the most common reasons for failure to produce clean gas.



The Benefits of Drying Biomass

Demand for fuel has also grown exponentially. However due to the time required to air season fuel (6-18 months) the market has struggled to keep up with demand and the result is a massive opportunity for those looking to force dry biomass fuels.

The benefits of drying biomass fuels are numerous:

- Drying allows a fast and efficient conversion of wet, freshly harvested timber into useable fuel in days rather than months.

- Removes the need for space associated with air seasoning timber over 6-18months.
- Allows fuel suppliers to react fast to market demand.
- Financial viability through the renewable heat incentives
- Production of high grade biomass fuel to 20-25% moisture content, ideal for biomass boilers.
- Ability to utilise waste heat or heat derived from low grade biomass further enhancing the financial viability.
- Production of dry fuel inline with demand; exact quantity of fuel can be contract dried when required.

STORAGE AND HANDLING OF BIOMASS

Sufficient biomass storage is necessary to accommodate seasonality of production and ensure regular supply to the biomass utilization plant. The type of storage will depend on the properties of the biomass, especially moisture content.

For high moisture biomass intended to be used wet, such as in fermentation and anaerobic digestion systems, wet storage systems can be used, with storage times closely controlled to avoid excessive degradation of feedstock. Storage systems typically used with dry agricultural residues should be protected against spontaneous combustion and excess decomposition, and the maximum storage moisture depends on the type of storage employed.

Consistent and reliable supply of biomass is crucial for any biomass project

Moisture limits must be observed to avoid spontaneous combustion and the emission of regulated compounds. Cost of storage is important to the overall feasibility of the biomass enterprise. In some cases, the storage can be on the same site as the source of the feedstock. In others, necessary volumes can only be achieved by combining the feedstock from a number of relatively close sources. Typically, delivery within about 50 miles is economic, but longer range transport is sometimes acceptable, especially when disposal fees can be reduced.

Storage of biomass fuels is expensive and increases with capacity.

Agricultural residues such as wheat straw, rice husk, rice straw and corn stover are usually spread or windrowed behind the grain harvesters for later baling. Typically these residues are left in the field to air dry to moisture levels below about 14% preferred for bales in stacks or large piles of loose material.

After collection, biomass may be stored in the open or protected from the elements by tarps or various structures. Biomass pelletization may be employed to increase bulk density and reduce storage and transport volume and cost.

Biomass Storage Options

- Feedstock is hauled directly to the plant with no storage at the production site.
- Feedstock is stored at the production site and then transported to the plant as needed.
- Feedstock is stored at a collective storage facility and then transported to the plant from

the intermediate storage location.

Biomass Storage Systems

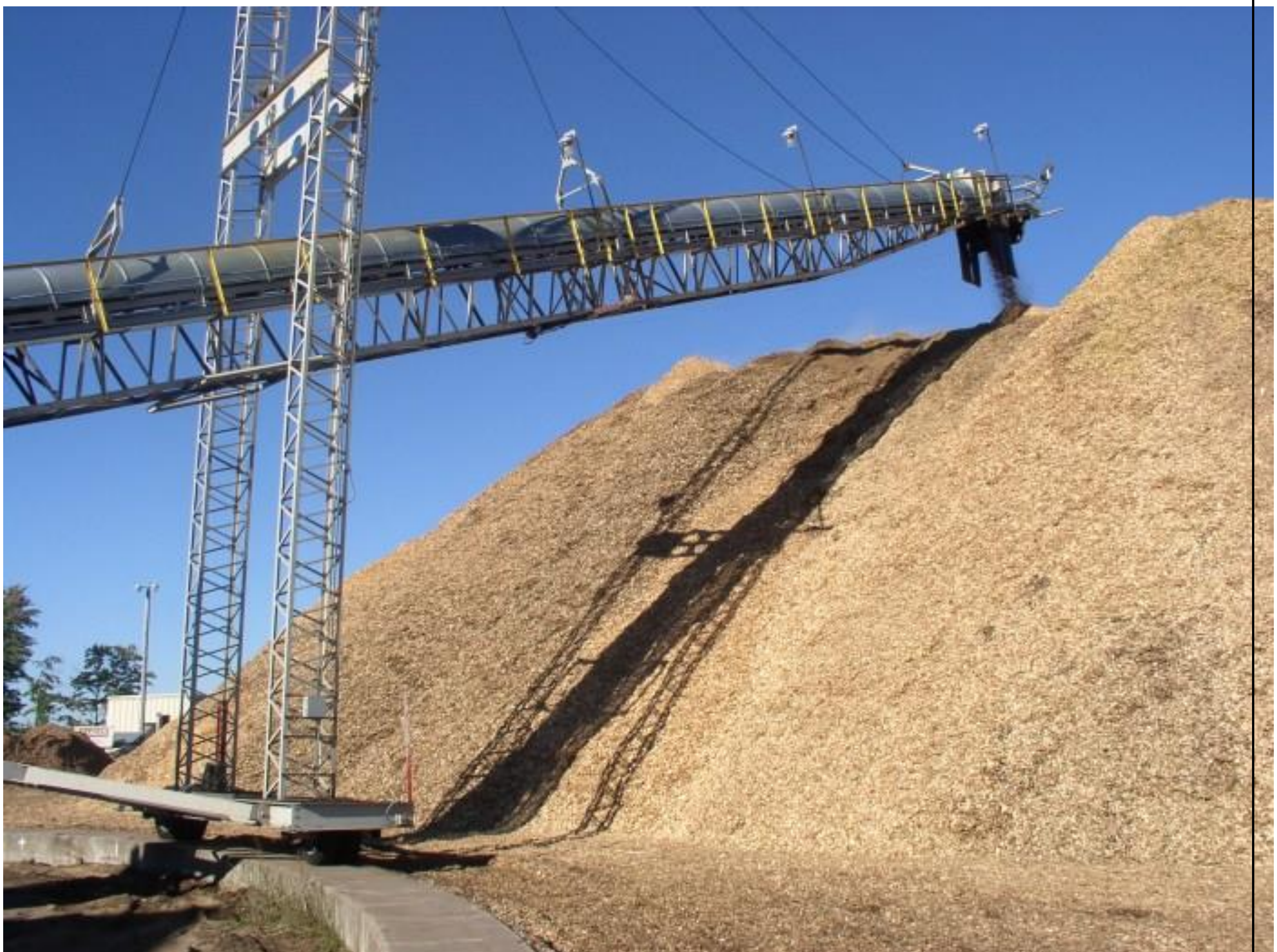
The type of biomass storage system used at the production site, intermediate site, or plant can greatly affect the cost and the quality of the fuel. The most expensive storage systems, no doubt, are the most efficient in terms of maintaining the high fuel quality. Typical storage systems, ranked from highest cost to lowest cost, include:

- Enclosed structure with crushed rock floor
- Open structure with crushed rock floor
- Reusable tarp on crushed rock
- Outside unprotected on crushed rock
- Outside unprotected on ground
- Subterranean

The storage of biomass is often necessary due to its seasonal production versus the need to produce energy all year round. Therefore to provide a constant and regular supply of fuel for the plant requires either storage or multi-feedstock to be used, both of which tend to add cost to the system.

Reducing the cost of handling and stable storage of biomass feedstock are both critical to developing a sustainable infrastructure capable of supplying large quantities of biomass to biomass processing plants. Storage and handling of biomass fuels is expensive and increases with capacity. The most suitable type of fuel store for solid biomass fuel depends on space available and the physical characteristics of the biomass fuel.

The physical handling of biomass fuels during collection or at a processing plant can be challenging task, particularly for solid biomass. Biomass fuels tend to vary with density, moisture content and particle size and can also be corrosive. Therefore biomass fuel handling equipment is often a difficult part of a plant to adequately design, maintain and operate.



The design and equipment choice for the fuel handling system, including preparation and refinement systems is carried out in accordance with the plant configuration. This is of special importance when the biomass is not homogeneous and contains impurities, typically for forest and agricultural wastes. Some of the common problems encountered have been the unpopular design and undersized fuel handling, preparation and feeding systems.

The fuel handling core systems and equipment are dependent on both the raw fuel type and condition as well as on the conversion/combustion technology employed. The core equipment in a biomass power plant include the following:

1. Fuel reception
2. Fuel weighing systems
3. Receiving bunkers
4. Bunker discharge systems (stoker, screw, grab bucket)
5. Fuel preparation
6. Fuel drying systems
7. Crushers
8. Chippers
9. Screening systems
10. Shredding systems
11. Grinding systems (for pulverised fuel burners)
12. Safety systems (explosion relieve, emergency discharge, fire detections etc)
13. Fuel transport and feeding
14. Push floors
15. Belt feeders
16. Conveyers and Elevators
17. Tube feeders
18. Fuel hoppers and silos (refined fuel)
19. Hopper, bunker and silo discharge

20. Feeding stokers

21. Feeding screws

22. Rotary valves

To enable any available biomass resource to be matched with the end use energy carrier required (heat, electricity or transport fuels) the correct selection of conversion technologies is required. Since the forms in which biomass can be used for energy are diverse, optimal resources, technologies and entire systems will be shaped by local conditions, both physical and socio-economic in nature.

THERMO CHEMICAL CONVERSION OF LIGNO CELLULOSES BIOMASS

Lignocellulosic biomass can be converted into fuels and chemicals using thermochemical or biochemical process pathways. Thermochemical technologies apply heat and chemical processes in order to produce bioenergy from biomass. There are four main thermochemical conversion processes: direct combustion, gasification, pyrolysis and liquefaction. Direct combustion produces heat while the three latter can produce various types of energy carriers that can be converted into fuels.

Direct combustion

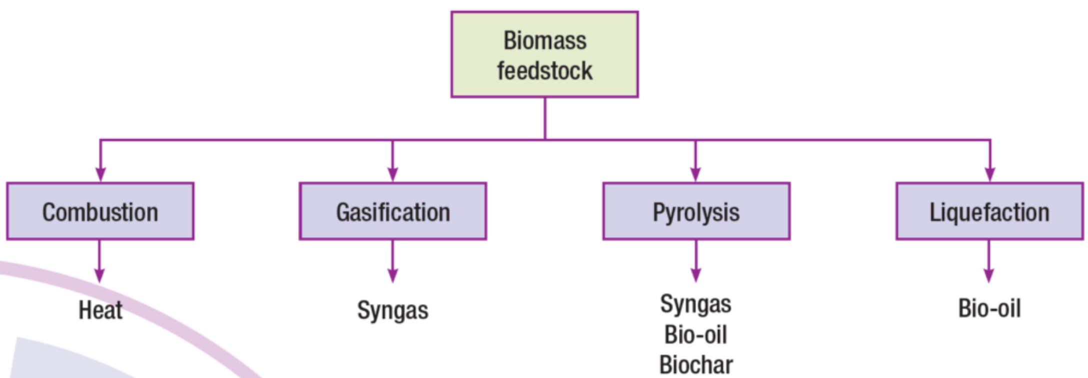
Direct combustion is the burning of biomass in open air, or, in the presence of excess air, converting the chemical energy stored in biomass into heat, mechanical power or electricity. Direct combustion is carried out using stoves, furnaces, steam turbines, or boilers at a temperature range starting at 800°C. All types of biomass can be burned, but in practice, direct combustion is only performed for biomass that has low moisture content (less than 50%). Biomass containing higher levels of moisture needs to be dried prior to combustion, or it may be better suited to biochemical conversion.

Gasification

Gasification is the partial oxidation of biomass at high temperatures (over 700°C) in the presence of a gasification agent, which can be steam, oxygen, air or a combination of these. The resulting gas mixture is called syngas or producer gas, and can be used in various processes to produce liquid fuels such as methanol, ethanol and Fischer-Tropsch diesel, and gaseous fuels, such as hydrogen and methane.

Syngas is comprised mainly of hydrogen and carbon monoxide, but could also contain methane, carbon dioxide, light hydrocarbons (e.g. ethane and propane) and heavy hydrocarbons (e.g. tars). Undesirable gases, such as hydrogen sulfide may also be present. The composition of the syngas depends on the type of biomass, the gasifier, the gasification agent, and on the temperature used in the process. Generally, when the biomass has high content of carbon and oxygen, the syngas produced via gasification is rich in carbon monoxide and carbon dioxide.

The most common biomass feedstocks used in the gasification process to produce biofuels are different kinds of wood, forestry wastes and agricultural residues. The heat for the high temperature gasification process can be supplied either directly by oxidation of part of the biomass in the gasifier, or indirectly by transferring energy to the gasifier externally.



Thermochemical conversion processes and the energy carriers produced.

Pyrolysis

Pyrolysis is the thermal decomposition of biomass to liquid, solid and gaseous fractions at high temperatures in the absence of oxygen in order to avoid significant levels of combustion. The liquid fraction is called bio-oil or bio-crude; a dark brown, viscous liquid with a high density, composed by a mixture of oxygen-containing organic compounds. Due to its high oxygen content, bio-oil is not suitable for direct use as a drop-in transportation fuel. However, it can be easily transported and stored, and after upgrading it has the potential to substitute crude oil, which makes it the most interesting product of pyrolysis. The solid fraction obtained from pyrolysis is called biochar, i.e. charcoal made from biomass, and the gasous fraction is syngas. The relative proportions of these fractions depend on the type of reactor employed and the feedstock used. It is controlled by varying the temperature, the heating rate and the residence time of the material in the reactor.

Depending on the heating rate employed, there are three main types of pyrolysis processes: slow, fast and flash pyrolysis. Slow pyrolysis has been used for thousands of years for the production of solid fuel. It is a decomposition process at relatively low temperatures (up to 500°C) and low heating rates (below 10°C/min), which takes several hours to complete, and results in solid biochar as the main product.

Fast pyrolysis is currently the most widely used process. It occurs at controlled temperature of around 500°C employing relatively high heating rates and only takes a few seconds to complete. The key product from fast pyrolysis is bio-oil (60-75%). In addition, biochar (15-25%) and syngas (10-20%) are also produced.

When heating rates and reaction temperatures are even higher, and the reaction time is shorter than that of fast pyrolysis, the process can be described as flash pyrolysis. Flash pyrolysis can result in a high yield of bio-oil and high conversion efficiencies (up to 70-75%).

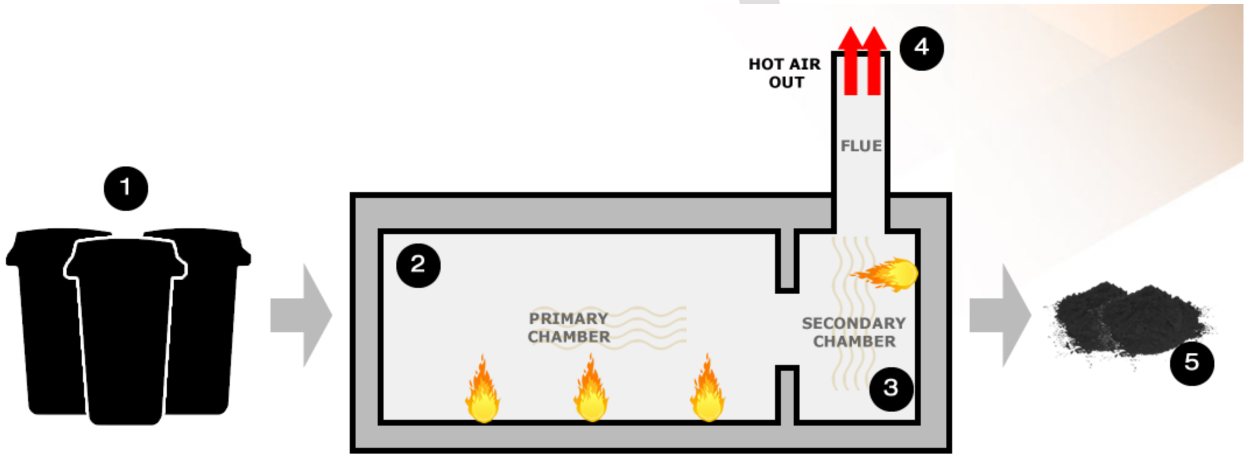
Liquefaction

Hydrothermal liquefaction is the conversion of biomass to bio-oil in the presence of water, with or without a catalyst. During hydrothermal liquefaction, large compounds in the biomass are broken down into unstable shorter molecules that in turn reattach to each other and form bio-oil. In contrast to pyrolysis and gasification, the liquefaction process does not require the use of dry biomass, which reduces the cost of drying. The resulting bio-oil has lower oxygen content than the bio-oil obtained from pyrolysis, and therefore, it requires less upgrading prior to utilization as a transportation fuel.

INCININERATION

Incineration is the process of combusting the organic elements within waste streams. Industrially this process is also known as ‘thermal treatment’.

. There are 2 main by-products to incineration. The first is inert bottom ash which is mostly formed by the in-organic elements of your waste stream, and the second is flue gas which providing the appropriate gas cleaning systems have been specified Is safe to let dispel into the atmosphere.



Parts of an Incinerator

The parts of most incinerators are quite standard, the main factor when selecting these parts is their ability to last and operate well under the high stress environments witnessed in incineration.

- **Primary Chamber (Combustion Chamber)** – this is where the waste is loaded and ignited. In most incinerators the ignition occurs due to the high ambient temperatures being retained within the chambers lining.
- **Secondary Chamber** – sometimes also called the ‘afterburner’ chamber is required by law in Europe, USA, Australia and Canada prevents the formation of harmful particulates. In many countries the law stipulates that all flue gas must be resident in this secondary chamber for at last 2 seconds at 850&Deg;C.
- **Flue Stack** – also know as the chimney. Most incinerators require a stack height of at

least 3m. This will be considerably higher in more built up areas or where atmospheric conditions dictate.

- **Control Panel & Thermocouples** – these control the operation of the machine and ensure the chambers are up to temperature before any waste is loaded for incineration.
- **Burners** – Most modern incinerators are fitted with low NOx or modulated gas flow burners to increase.
- **Fuel Tanks** – Fuel tanks should be bunted to ensure safe storage of fuel.

Incineration Process

Preparation of waste stream – most waste streams will require some pre-preparation. In the long-term this can have a huge impact on the savings you can make.

- Sort – remove any high value recyclable items for resale.
- Shred – normalize the particle size and add air to mix
- Dry – we suggest max of 30% moisture to ensure best efficiency
- Determine batch size – establish the optimum batch size based on volume you can burn for lowest cost in lowest time.
- De-ash – once chamber has cooled you can easily de-ash the system ready for the next batch.
- Spot check – ensure chamber, burners and fuel lines are all in good condition
- Re-load – load chamber for next operation

MODULE III

WIND ENERGY ENGINEERING

INTRODUCTION TO WIND ENERGY ENGINEERING

In ancient times, wind was used to move the sails of the ships. In this chapter, we will see how wind energy is used to generate electricity.

A **turbine** converts the kinetic energy of the wind to useful mechanical energy. This energy could be used in mechanical form or turn generator turbines and provide electricity. Just like in the hydropower systems, wind energy is harnessed through conversion of the wind kinetic energy to mechanical energy.

The wind turbines are largely classified into two types- Horizontal Axis Wind Turbines and Vertical Axis Wind Turbines. Large areas installed with wind turbines, that is, wind farms are increasingly emerging today.

Wind Characteristics

There are general characteristics of wind while others are more specific to the site. Some of the site specific characteristics include −

- **Mean wind speed** − This estimates the annual wind yield though it does not give the distributions.
- **Wind speed distribution** − There are three aspects namely annual, diurnal and seasonal characteristics. Understanding the wind speed variations and the spread is necessary when choosing a site.
- **Turbulance** − This is the chaotic movement of wind in unpredictable patterns. Turbulance results from continuously changing properties of wind motion that impact on energy production and fatigue on blades.
- **Long term fluctuation** − Irregular wind causes unpredictable energy supply. Before a wind turbine is set, the area should be studied for a constant wind flux.
- **Distribution of wind direction** − This is more significant in positioning of the blades especially for horizontal axis types.
- **Wind shear** − Shear is change in wind direction, speed or the height at which the maximum velocity occurs.

Wind Speed Patterns

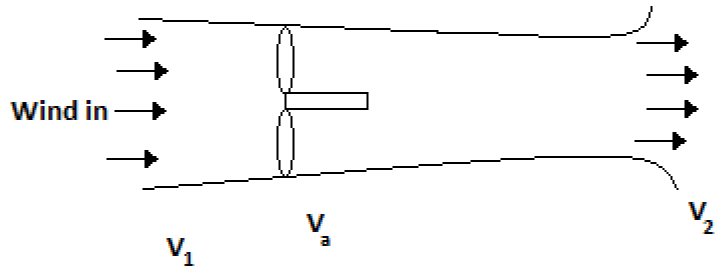
Wind patterns are important and are often analyzed using a **wind spectrum**. A high value of the wind spectrum represents a large change in the wind speed at the given time interval. If represented on a graph, the peaks depict turbulences that occur with time.

Wind speed distribution

There are three distributions −

- **Diurnal** − Caused by the difference between temperatures during the day and at night.
- **Depressions** − Occur with four-day intervals along the coastal region.
- **Annual** − Distribution is latitude dependent.

To understand wind energy, we subscribe to the theory of conservation of mass and conservation of energy. A duct shown below is assumed to represent wind flowing in and out of the blades of the turbine.



The velocity Va is assumed to be the average of V1 and V2. Kinetic energy at the mouth of the tube is given by −

KE = 1/2 mV2

KE of energy changed = 1/2 mV12 - 1/2 mV22

1/2 m(V12 - V22)

Since m = p.A.Va then KE change, Pk = 1/2 p.A.Va (V12 - V22)

On further simplification, the estimated wind energy is give as −

KE, pk = 0.5925 * 1/2pAV13

Blade Element Theory

The blade element theory assumes that the flow at a given part of a wind turbine blade does not affect the adjacent parts. This subdivision on the blade is called annulus. The momentum is calculated for each annulus. All the resultant values are then summed up to represent the blade and hence the entire propeller.

On each annulus, an equally distributed velocity is assumed to have been induced.

Dynamic Matching

The dynamic inflow model was incorporated to improve the estimations by the Blade Element and Momentum theory. The basic dynamic in flow theory concept helps estimate the effect of blade turbulence. The swept area is given a dynamic state to help in deriving estimate mean velocity.

The BEM theory gives estimates only at steady wind but it is obvious that turbulences must occur. However, this is accounted for by the basic dynamic inflow model to provide a more realistic estimate.

Wind energy produced, especially in the horizontal axis type, is known to be the product of tip speed, the total number of blades used and the lift-to-drag ratio of the side with an aerofoil. The readjustment to a new steady state of equilibrium is well explained by the Dynamic Inflow Method (DIM).

Dynamic Inflow Method

DIM is also known as dynamic wake theory and is based on the induced flow, which is normally not steady. It calculates the inflow vertical to the rotor taking into consideration its effect on the dynamic flow.

This simply takes into consideration the wake effect or simply the velocity of the air vertically aligned with the rotors caused by the turning of the blades. It however assumes the tangential velocity to be steady. This is referred to as the Wake effect and its drag lowers the efficiency of a wind turbine.

Electricity Generation

The kinetic energy in wind is converted to electricity by wind turbines. They use the ancient concept used in windmills though with inherent technology, such as sensors, to detect wind direction. Some wind turbines have braking system to halt in case of strong winds to protect the rotor and blades from damage.

There are gears connected to the rotor shaft to accelerate the blades to a speed suitable for the generator. Inside the generator, electromagnetic induction (the basic method of conversion from mechanical energy to electricity) occurs. The shaft rotates a cylindrical magnet against an electric wire coil.

All electricity from the turbines in a wind power station is assimilated to a grid system and converted to a high voltage. This is actually the conventional technique of transmitting electricity in the grid system.

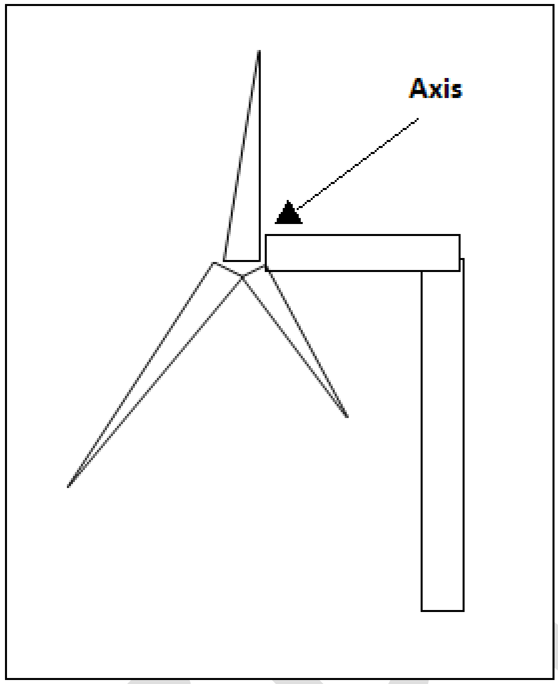
Large surface-tipped blades are needed although this should be determined by the noise that results from wide blades. A wind farm may have up to 100 generators, which will result in more noise.

There are two broad classifications of wind turbines −

- Horizontal Axis Wind Turbines (HAWT)
- Vertical Axis Wind Turbines (VAWT)

Let’s discuss these two types of wind turbines in a little detail.

Horizontal Axis Wind Turbines

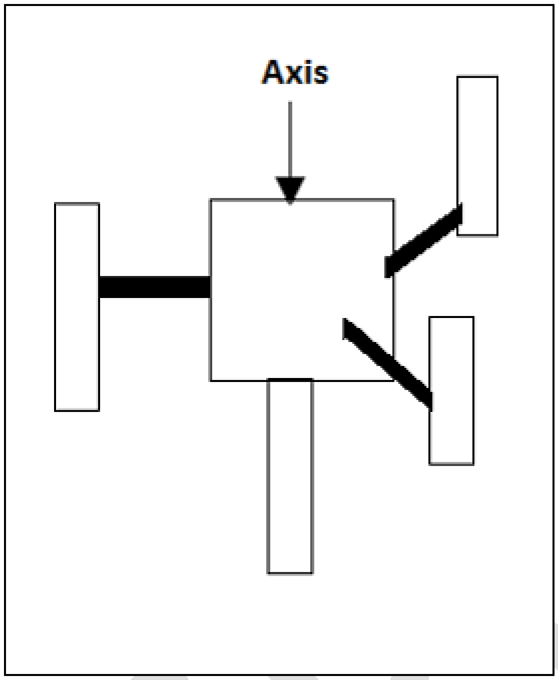


These are windmill-like turbines with the top of the shaft pointing towards the wind direction. Since they have to be pointed towards the wind, smaller turbines are directed by wind vanes mounted on the structure. Larger turbines have wind sensors with servo to turn the turbines.

They are also fitted with gear-boxes to accelerate the slow rotation to make it strong enough for the generator turbines. The blades are stiff enough to avoid breaking or bending due to the turning moment of the wind.

This type is mounted on a tower; hence they experience high velocity winds. They are slightly bent to reduce the sweep area. A lower sweep area reduces resistance, which may cause fatigue and failure.

Vertical Axis Wind Turbines



The main root is mounted on the vertical shaft. This eliminates the difficulties associated with horizontal wind turbines. The subtypes include −

Darius Wind Turbine

This is also known as the egg-beater turbine and resembles a huge egg beater. It is efficient but may have more down times and hence less reliable. To improve on solidity (blade area over rotor area) three or more blades should be used.

Savonious Wind Turbine

These types have a greater reliability than Darius turbines. The problem is that they cannot be mounted on top of towers. Therefore, they are exposed to turbulent and irregular wind patterns. Since they are drag-type of turbines they are less efficient compared to the HAWT. The advantage is that they are able to withstand extreme turbulence.

Most VAWT cannot self-start and require external energy to give them a jolt. For optimal performance, VAWTs should be mounted on roof-tops. The roof channels the wind into the blades.

MEASUREMENT AND INSTRUMENTATION OF WIND

The instruments used to measure wind are known as anemometers and can record wind speed, direction and the strength of gusts.

The normal unit of wind speed is the knot (*nautical mile per hour = 0.51 m sec-1 = 1.15 mph*). Wind direction is measured relative to true north (*not magnetic north*) and is reported from where the wind is blowing. An easterly wind blows from the east or 90 degrees, a southerly from the south or 180 degrees and a westerly from the west or 270 degrees.

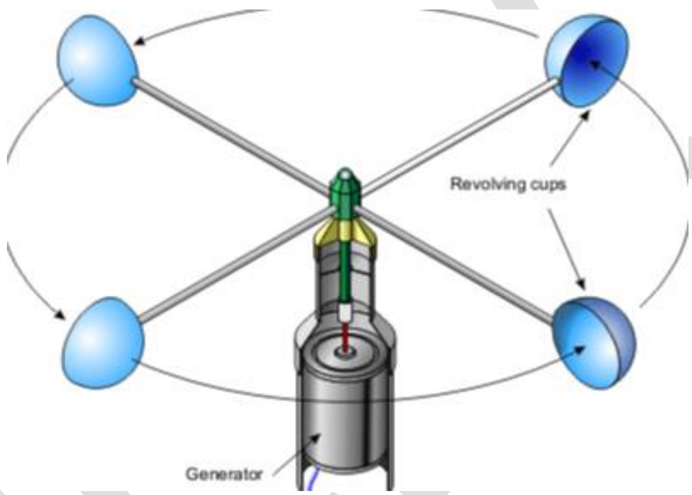
Wind speed normally increases with height above the earth's surface and is much affected by such factors as the roughness of the ground and the presence of buildings, trees and other obstacles in the vicinity.

The optimal exposure for the measurement of wind is over level ground of uniform roughness with no large obstacles within 300 m of the tower. In practice few sites in the observing network meet this requirement exactly for all incident wind directions, but most are reasonably representative of an open site.

Cup anemometer

Wind speed is normally measured by a cup anemometer consisting of three or four cups, conical or hemispherical in shape, mounted symmetrically about a vertical spindle. The wind blowing into the cups causes the spindle to rotate. In standard instruments the design of the cups is such that the rate of rotation is proportional to the speed of the wind to a sufficiently close approximation.

At intervals of no longer than five years, anemometers are calibrated in a wind tunnel to identify any departures in the relationship between spindle rotation and wind speed specified by the manufacturer. Calibration corrections are applied to the measured wind speed.



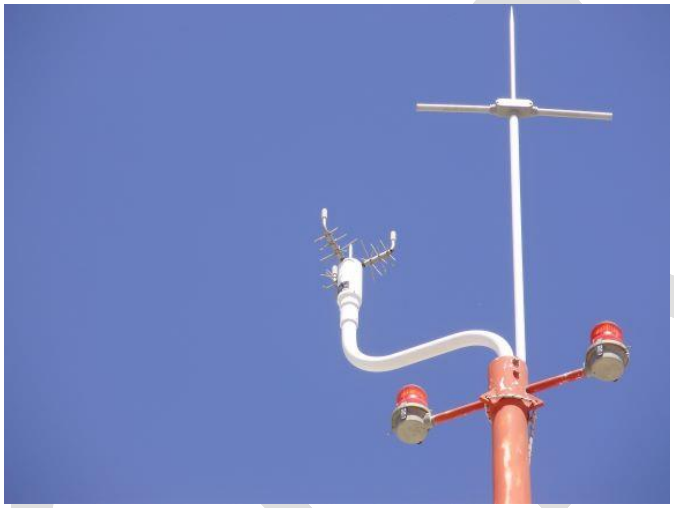
Measuring wind direction

Wind direction is measured by a vane consisting of a thin horizontal arm carrying a vertical flat plate at one end with its edge to the wind and at the other end a balance weight which also serves as a pointer. The arm is carried on a vertical spindle mounted on bearings which allow it to turn freely in the wind. The anemometer and wind vane are each attached to a horizontal supporting arm at the top of a 10 m mast (see image above).

Sonic anemometer

Where wind measurements are made in extreme weather conditions, such as on the top of mountains, a heated sonic anemometer is used (see above image) having no moving parts. The instrument measures the speed of acoustic signals transmitted between two transducers located at the end of thin arms. Measurements from two pairs of transducers can be combined to yield an estimate of wind speed and direction.

The distortion of the air flow by the structure supporting the transducers is a problem which can be minimized by applying corrections based on calibrations in a wind tunnel.



Measuring gusts and wind intensity

Because wind is an element that varies rapidly over very short periods of time it is sampled at high frequency (*every 0.25 sec*) to capture the intensity of gusts, or short-lived peaks in speed, which inflict greatest damage in storms. The gust speed and direction are defined by the maximum three second average wind speed occurring in any period.

A better measure of the overall wind intensity is defined by the average speed and direction over the ten minute period leading up to the reporting time. Mean wind over other averaging periods may also be calculated. A gale is defined as a surface wind of mean speed of 34-40 knots, averaged over a period of ten minutes. Terms such as 'severe gale', 'storm', etc are also used to describe winds of 41 knots or greater.

BEAU FORT SCALE / NUMBER

Beaufort scale, in full **Beaufort wind force scale**, scale devised in 1805 by Commander (later

Admiral and Knight Commander of the Bath) Francis Beaufort of the British navy for observing and classifying wind force at sea. Originally based on the effect of the wind on a full-rigged man-of-war, in 1838 it became mandatory for log entries in all ships in the Royal Navy. Altered to include observations of the state of the sea and phenomena on land as criteria, it was adopted in 1874 by the International Meteorological Committee for international use in weather telegraphy.

The Beaufort scale is useful for estimating wind power without wind instruments.

0: Calm and still: Smoke rises vertically.

1. Light winds at 1-5 kph (1-3 mph): Smoke drift shows wind direction.

2. Light breeze at 6-11 kph (4-7 mph): Wind can be felt on face, flag ripples.

3. Gentle breeze at 12-19 kph (8-12 mph): Flag waves.

4. Gentle breeze at 20-28 kph (13-18 mph): Paper and leaves are scattered.

5. Fresh breeze at 29-38 kph (19-24 mph): Small trees sway, whitecaps form on waves.

6. Strong breeze at 39-49 kph (25-31 mph): Umbrellas are hard to use, large branches on trees move.

7. Moderate gale at 50-61 kph (32-38 mph): Trees sway, walking in the wind is difficult.

8. Fresh gale at 62-74 kph (39-46 mph): Twigs and branches break off of trees.

9. Strong gale at 75-88 kph (47-54 mph): Roof tiles blow off buildings.

10. Whole gale at 89-102 kph (55-63 mph): Trees are uprooted.

11. Storm at 103-118 kph (64-73 mph): Widespread damage to vegetation and buildings, nearly no visibility at sea.

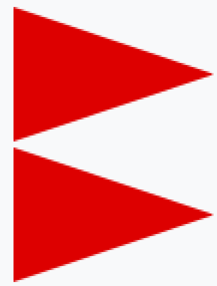
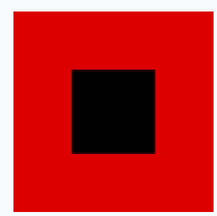
12. Hurricane at 119-220 kph (74-136 mph): Category 1 hurricane, Category 1 tornado.

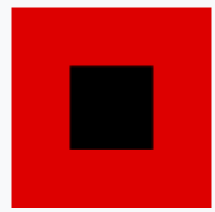
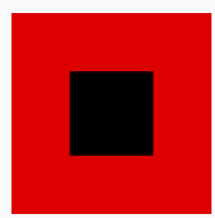
Widespread destruction.

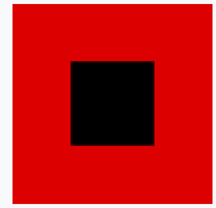
Beaufort number	Description	Wind speed	Wave height	Sea conditions	Land conditions	Associated warning flag
0	Calm	< 1 knot < 1 mph < 2 km/h < 0.5 m/s	0 ft (0 m)	Sea like a mirror	Smoke rises vertically.	
1	Light air	1–3 knots 1–3 mph 2–5 km/h 0.5–1.5 m/s	0–1 ft 0–0.3 m	Ripples with appearance of scales are formed, without foam crests	Direction shown by smoke drift but not by wind vanes.	
2	Light breeze	4–6 knots 4–7 mph 6–11 km/h 1.6–3.3 m/s	1–2 ft 0.3–0.6 m	Small wavelets still short but more pronounced; crests have a glassy appearance but do not break	Wind felt on face; leaves rustle; wind vane moved by wind.	

3	Gentle breeze	7–10 knots	2–4 ft	Large wavelets; crests begin to break; foam of glassy appearance; perhaps scattered white horses	Leaves and small twigs in constant motion; light flags extended.	
		8–12 mph				
		12–19 km/h	0.6–1.2 m			
		3.4–5.5 m/s				
4	Moderate breeze	11–16 knots	3.5–6 ft	Small waves becoming longer; fairly frequent white horses	Raises dust and loose paper; small branches moved.	
		13–18 mph				
		20–28 km/h	1–2 m			
		5.5–7.9 m/s				
5	Fresh breeze	17–21 knots	6–10 ft	Moderate waves taking a more pronounced long form; many white horses are formed; chance of some spray	Small trees in leaf begin to sway; crested wavelets form on inland waters.	
		19–24 mph				
		29–38 km/h	2–3 m			

		8– 10.7 m/s				
6	Strong breeze	22– 27 knots 25– 31 mph 39– 49 km/h 10.8– 13.8 m/s	9–13 ft 3–4 m	Large waves begin to form; the white foam crests are more extensive everywhere; probably some spray	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty.	
7	High wind, moderate gale, near gale	28– 33 knots 32– 38 mph 50– 61 km/h 13.9– 17.1 m/s	13–19 ft 4–5.5 m	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind; spindrift b egins to be seen	Whole trees in motion; inconvenience felt when walking against the wind.	
8	Gale, fresh gale	34– 40 knots 39– 46 mph	18–25 ft	Moderately high waves of greater length; edges of crests break into spindrift; foam	Twigs break off trees; generally impedes progress.	

		62–74 km/h 17.2–20.7 m/s	5.5–7.5 m	is blown in well-marked streaks along the direction of the wind		
9	Strong/severe gale	41–47 knots 47–54 mph 75–88 km/h 20.8–24.4 m/s	23–32 ft 7–10 m	High waves; dense streaks of foam along the direction of the wind; sea begins to roll; spray affects visibility	Slight structural damage (chimney pots and slates removed).	
10	Storm, whole gale	48–55 knots 55–63 mph 89–102 km/h	29–41 ft 9–12.5 m	Very high waves with long overhanging crests; resulting foam in great patches is blown in dense white streaks along the direction of the wind; on the	Seldom experienced inland; trees uprooted; considerable structural damage.	

		24.5–28.4 m/s		whole the surface of the sea takes on a white appearance; rolling of the sea becomes heavy; visibility affected		
11	Violent storm	56–63 knots 64–72 mph 103–117 km/h 28.5–32.6 m/s	37–52 ft 11.5–16 m	Exceptionally high waves; small- and medium-sized ships might be for a long time lost to view behind the waves; sea is covered with long white patches of foam; everywhere the edges of the wave crests are blown into foam; visibility affected	Very rarely experienced; accompanied by widespread damage.	
12	Hurricane force	≥ 64 knots ≥ 73 mph ≥ 118 km/h	≥ 46 ft ≥ 14 m	The air is filled with foam and spray; sea is completely white with driving spray; visibility very seriously affected	Devastation.	

		≥ 32.7 m/s				

The Beaufort scale is not an exact nor an objective scale; it was based on visual and subjective observation of a ship and of the sea. The corresponding integral wind speeds were determined later, but the values in different units were never made equivalent.

The scale is used in the Shipping Forecasts broadcast on BBC Radio 4 in the United Kingdom, and in the Sea Area Forecast from Met Éireann, the Irish Meteorological Service. Met Éireann issues a "Small Craft Warning" if winds of Beaufort force 6 (mean wind speed exceeding 22 knots) are expected up to 10 nautical miles offshore. Other warnings are issued by Met Éireann for Irish coastal waters, which are regarded as extending 30 miles out from the coastline, and the Irish Sea or part thereof: "Gale Warnings" are issued if winds of Beaufort force 8 are expected; "Strong Gale Warnings" are issued if winds of Beaufort force 9 or frequent gusts of at least 52 knots are expected.; "Storm Force Warnings" are issued if Beaufort force 10 or frequent gusts of at least 61 knots are expected; "Violent Storm Force Warnings" are issued if Beaufort force 11 or frequent gusts of at least 69 knots are expected; "Hurricane Force Warnings" are issued if winds of greater than 64 knots are expected.

This scale is also widely used in the Netherlands, Germany,[13] Greece, China, Taiwan, Hong Kong, Malta, and Macau, although with some differences between them. Taiwan uses the Beaufort scale with the extension to 17 noted above. China also switched to this extended version without prior notice on the morning of 15 May 2006,[14] and the extended scale was immediately put to use for Typhoon Chanchu. Hong Kong and Macau retain force 12 as the maximum.

In the United States, winds of force 6 or 7 result in the issuance of a small craft advisory, with force 8 or 9 winds bringing about a gale warning, force 10 or 11 a storm warning ("a tropical storm warning" being issued instead of the latter two if the winds relate to a tropical cyclone), and force 12 a hurricane-force wind warning (or hurricane warning if related to a tropical cyclone). A set of red warning flags (daylight) and red warning lights (night time) is displayed at shore establishments which coincide with the various levels of warning.[citation needed]

In Canada, maritime winds forecast to be in the range of 6 to 7 are designated as "strong"; 8 to 9 "gale force"; 10 to 11 "storm force"; 12 "hurricane force". Appropriate wind warnings are issued by Environment Canada's Meteorological Service of Canada: strong wind warning, gale (force wind) warning, storm (force wind) warning and hurricane-force wind warning. These designations were standardized nationally in 2008, whereas "light wind" can refer to 0 to 12 or 0 to 15 knots and "moderate wind" 12 to 19 or 16 to 19 knots, depending on regional custom, definition or practice. Prior to 2008, a "strong wind warning" would have been referred to as a "small craft warning" by Environment Canada, similar to US terminology. (Canada and the USA have the Great Lakes in common.

Weather scale

Beaufort's name was also attached to the Beaufort scale for weather reporting:

Symbol	Interpretation
b	blue sky
c	detached clouds
d	drizzling rain
f	fog
g	dark, gloomy
h	hail
l	lightning
m	misty (hazy)

o	overcast
p	passing showers
q	squally
r	rain
s	snow
t	thunder
u	ugly (threatening)
v	visibility (unusual transparency)
w	wet, dew

In this scale the weather could be reported as "s.c." for snow and detached cloud or "g.r.q." for dark, rain and squally

GUST PARAMETERS

A **gust** or **wind gust** is a brief increase in the speed of the wind, usually less than 20 seconds. It is of a more transient character than a squall, which lasts minutes, and is followed by a lull or slackening in the wind speed. Generally, winds are least gusty over large water surfaces and most gusty over rough land and near high buildings.

The wind is measured using an anemometer or estimated with a windsock. The average value of the latter is generally measured over a period of 2 minutes before the meteorological observation according to the World Meteorological Organization. Any significant variation at this mean wind during the ten minutes preceding the observation are noted as gusts in messages such as

METAR.

It is generally reported in METAR when the peak wind speed reaches at least 16 knots and the variation in wind speed between the peaks and average wind is at least 9 to 10 knots. In marine meteorology, the top speed of a burst is expressed in meters per second (m/s) or in knots, while the Beaufort scale is used for reporting the mean speed. When the maximum speed exceeds the average speed by 10 to 15 knots, the term *gusts* is used while *strong gusts* is used for departure of 15 to 25 knots, and *violent gusts* when it exceeds 25 knots.

Gust vs Wind

The difference between gust and wind is that gusts are actually 30 times stronger than the average sustained wind. Although gusts are a variation of wind, it is noteworthy that gusts commonly last less than 20 seconds.

Gusts are formed when winds meet obstacles such as a building or an irregular ground whereas winds are formed due to the atmospheric pressure difference caused by unequal heating of the earth's surface.

Another difference is that gusts hit suddenly as a strong surge of wind while winds are a steady flow of gasses from a high-pressure region to a low-pressure region. Unlike winds, gusts are not commonly seen over water bodies whereas wind can be anywhere, and everywhere there is a pressure difference.

Comparison Table Between Gust and Wind (in Tabular Form)

Parameter of Comparison	Gust	Wind
Strength	30% stronger than wind	30% weaker than gusts
Duration	Less than 20 seconds	Flows continually

Parameter of Comparison	Gust	Wind
Caused by	When winds hit an obstacle such as a high ground or building	Flow of air from high pressure to low pressure area
Geographic location	Flows mostly above the ground and occasionally over water	Flows both above ground and water
Factors affecting	Height of the obstacle, dynamics of the terrain, average wind speed, etc.	Earth's rotation, heating by the Sun, pressure difference in atmosphere, etc.

Gusts are a variation of wind that is formed when winds meet an obstacle such as a high terrain or a tall structure or buildings. Therefore gusts are commonly found over grounds and not so much on water bodies.

However, gust can also occasionally occur over water due to changes in wind speeds and wind direction causing turbulence and friction in the region. Gusts are formed over grounds due to friction between heavy cold air settling down and lighter thermal air rising.

Gusts are about 30% stronger and have a higher speed than average winds but are strongly determined by the average sustained wind speed. So the higher the average wind speed the stronger is a gust.

Besides average wind speed, other factors affecting gust are dynamics of the terrain, local topography, shape of the structure, and atmospheric pressure.

A gust is defined as a sudden surge of strong winds that typically last less than twenty seconds and is followed by a lull. Gusts are characterized by peak wind speed crossing 18 mph and a minimum of 10 mph difference between peak and lull wind speed.

Main Differences between Gust and Wind

- **The main difference between gust and wind** is that gusts are 30% stronger than average sustained winds.
- Another difference is that gusts are short-lived and are typically followed by a lull after 20 seconds while winds last longer.
- Gusts are caused by obstacles such as high grounds or tall structures and buildings while winds flow due to the difference in atmospheric pressure.
- Gusts are affected by factors such as local topography and sustained wind speeds while winds are determined by Earth's rotation, Sun's heating patterns, the pressure difference in the atmosphere, etc.
- A key difference between gust and wind is that gust is a part of wind whereas the term wind covers numerous types such as squalls, breeze, cyclones, etc.

What is Wind?

Winds are created when air flows from a region of high pressure to a region of low pressure. Wind speeds are measured using a device called an anemometer. In other words, they are a flow of gasses trying to get to a condition of equilibrium.

While varied atmospheric pressure is the main cause behind the formation wind, it is also very much affected by the Earth's rotation, the Sun's heating pattern, varied heating of the equator and poles, and many more. About two percent of Sun energy reaching Earth is converted into wind energy.

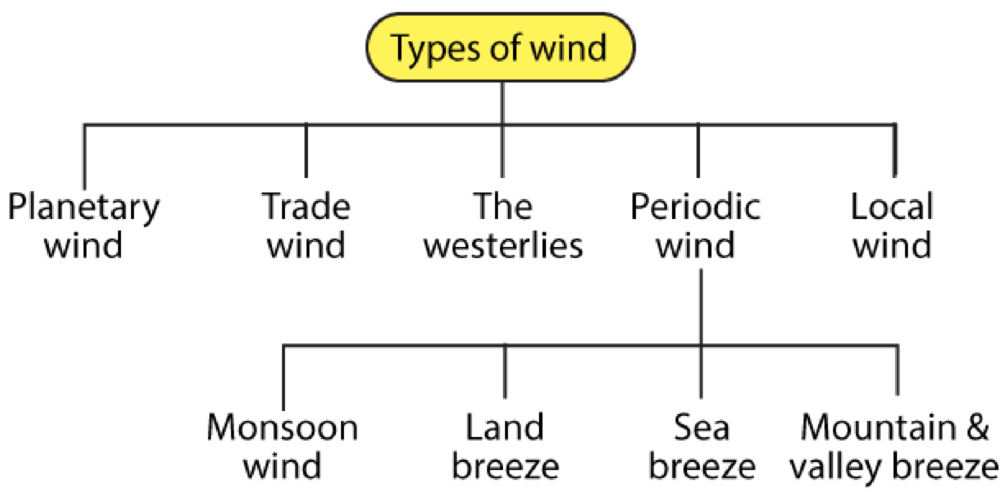
Winds are classified in numerous types depending upon its region of origin, wind speed, effects of the wind, causes of origin, the density of gasses, etc. They may be classified into gusts, squalls, breeze, or more fierce hurricanes, cyclones, and tornadoes.

They can also be classified into planetary and solar winds depending on their origin. Planetary winds are the result of gasses leaking out of Earth's atmosphere into space while solar winds are gasses released from the sun into space.

Types of Wind

Wind blowing above the earth surface may be classified into five major types:

- Planetary winds
- Trade winds
- The westerlies
- Periodic winds
    - Monsoon winds
    - Land breeze
    - Sea breeze
    - Mountain and valley breeze
- Local winds



Planetary Winds

Planetary winds comprise winds distributed throughout the lower atmosphere. The winds regularly blow throughout the year confined within latitudinal belts, mainly in north-east and south-east directions or from high-pressure polar-regions to low-pressure regions.

Trade Winds

These winds are also known as tropical easterlies and blow from the right in Northern hemisphere and to the left in the Southern hemisphere due to Coriolis effect and Ferrel's law. They start blowing from the sub-tropical high-pressure areas towards the equatorial low-pressure belt. In the Northern hemisphere, they blow as northeastern trades, and in the Southern hemisphere they blow as southeastern trades.

The Westerlies

These winds are also known as Shrieking Sixties, Furious Fifties, and Roaring Forties. They blow from the subtropical high-pressure belts towards sub-polar low-pressure belts. The westerlies of Southern hemisphere are stronger and constant than the westerlies of Nothern hemisphere.

Periodic Winds

These winds change their direction periodically as there is a change in the seasons. Following are the types of periodic winds:

- **Monsoon winds**: The temperature difference created by the Indian Ocean, Arabian Sea, Bay of Bengal and Himalayan wall forms the basis of monsoon in the Indian subcontinent.
- **Land breeze:** These winds blow from land to sea, carrying no moisture but dry and warm.
- **Sea breeze:** These winds blow from sea to land, carrying some moisture.
- **Mountain and valley breeze:** Valley breeze is the hot air blowing from the valley which flows up to the slopes of mountain slopes. In contrast, mountain breeze is the valley

breeze that is the cold air from the mountain flow towards the valley.

Local winds

The local winds include the sea and the land breeze created due to the pressure difference between the air over the sea and the land regions. Loo is the local winds that blow in the northern part of India.

How is Wind Measured?

The wind has speed as well as direction, to measure this parameter, two different devices are used:

- **Anemometers**

These instruments are a common weather station instrument which is used for measuring the speed of the wind. Cup anemometer, hot wire anemometer, windmill anemometer, sonic anemometer, and laser doppler anemometer are the different types of anemometer.

- **Wind vanes**

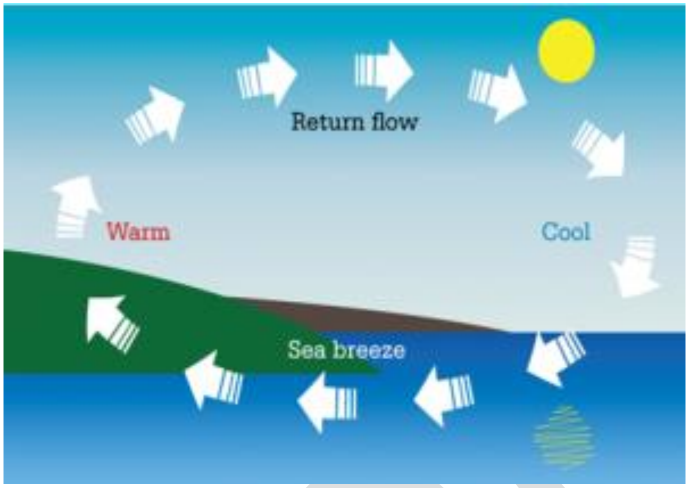
These devices are also known as weather vane, which is used for determining the direction of the wind.

Causes of Wind

The main cause of generation of wind is the uneven heating of two regions. Following are the examples of uneven heating we see around us:

What is uneven heating between land and sea?

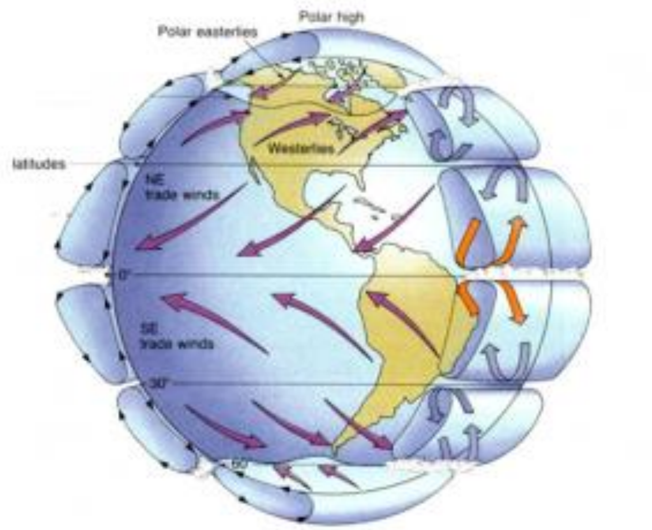
Seawater gets heated more slowly as compared to land. As the temperature of the land rises, the air above it gets heated by conduction. The density of warm air is less than the surrounding environment, because of which it rises, creating a vacuum in its place. The cooler air from the sea rushes to fill the vacuum which creates a cool coastal breeze. At night, the land cools off more quickly, which creates a temperature difference between the temperature onshore and that offshore. Because of this temperature difference, again, a pressure drop is created, establishing a land breeze.



The flow of Air between Land and Sea

What is uneven heating between equator and pole?

The equatorial and tropical regions (close to the equator) get the maximum heat from the sun; hence they get hotter than the polar regions. The air surrounding this region gets heated up and rises to create a vacuum. Cooler air from the poles rushes to fill the vacuum. The wind does not flow in the north-south direction because a change in direction is caused by the rotation of the earth.



The flow of Air between Equator and Pole

POWER INDEX LAW

The **wind profile power index law** is a relationship between the wind speeds at one height, and those at another. The power law is often used in wind power assessments where wind speeds at the height of a turbine (>~ 50 meters) must be estimated from near surface wind observations (~10 meters), or where wind speed data at various heights must be adjusted to a standard height prior to use. Wind profiles are generated and used in a number of atmospheric pollution dispersion models.

The wind profile of the atmospheric boundary layer (surface to around 2000 meters) is generally logarithmic in nature and is best approximated using the log wind profile equation that accounts for surface roughness and atmospheric stability. The wind profile power law relationship is often used as a substitute for the log wind profile when surface roughness or stability information is not available.

The wind profile power law relationship is:

$$u/ur = (z/zr)^{\alpha}$$

where u is the wind speed (in meters per second) at height z (in meters), and u_r is the known wind speed at a reference height z_r. The exponent (α) is an empirically derived coefficient that varies dependent upon the stability of the atmosphere. For neutral stability conditions, α is approximately 1/7, or 0.143.

In order to estimate the wind speed at a certain height *x*, the relationship would be rearranged to:

$$u_x = u_r(z_x/z_r)^{\alpha}$$

The value of 1/7 for α is commonly assumed to be constant in wind resource assessments, because the differences between the two levels are not usually so great as to introduce substantial errors into the estimates (usually < 50 m). However, when a constant exponent is used, it does not account for the roughness of the surface, the displacement of calm winds from the surface due to the presence of obstacles (i.e., zero-plane displacement), or the stability of the atmosphere. In places where trees or structures impede the near-surface wind, the use of a constant 1/7 exponent may yield quite erroneous estimates, and the log wind profile is preferred. Even under neutral stability conditions, an exponent of 0.11 is more appropriate over open water (e.g., for offshore wind farms), than 0.143, which is more applicable over open land surfaces.

Limits of Wind Power Law

The wind profile of the atmospheric boundary layer (surface to around 2000 metres) is generally logarithmic in nature and is best approximated using the log wind profile equation that accounts for surface roughness and atmospheric stability. The relationships between surface power and wind are often used as an alternative to logarithmic wind features when surface roughness or stability information is not available.

Applications of Wind Power Law

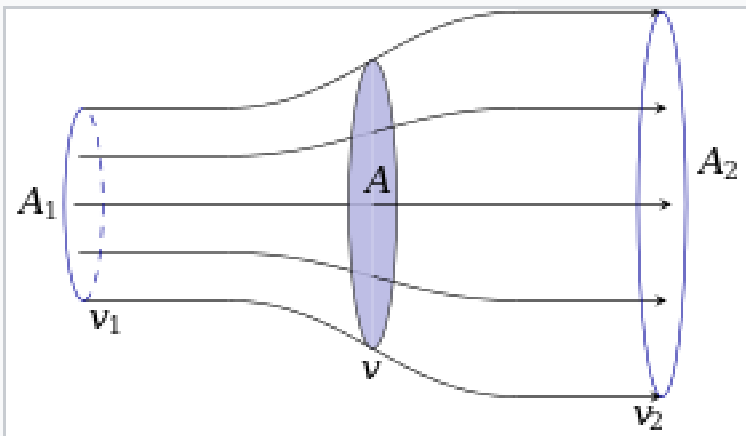
The power law is often used in wind power assessments where wind speeds at the height of a

turbine (50 metres) must be estimated from near surface wind observations (~10 metres), or where wind speed data at various heights must be adjusted to a standard height prior to use. Wind profiles are generated and used in a number of atmospheric pollution dispersion models.

BETZ LAW AND CONSTANT

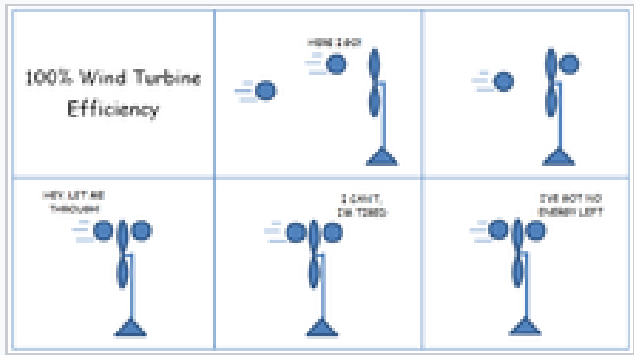
Betz's law indicates the maximum power that can be extracted from the wind, independent of the design of a wind turbine in open flow. It was published in 1919 by the German physicist Albert Betz. The law is derived from the principles of conservation of mass and momentum of the air stream flowing through an idealized "actuator disk" that extracts energy from the wind stream. According to Betz's law, no turbine can capture more than 16/27 (59.3%) of the kinetic energy in wind. The factor 16/27 (0.593) is known as Betz's coefficient. Practical utility-scale wind turbines achieve at peak 75–80% of the Betz limit.

The Betz limit is based on an open-disk actuator. If a diffuser is used to collect additional wind flow and direct it through the turbine, more energy can be extracted, but the limit still applies to the cross-section of the entire structure



Schematic of fluid flow through a disk-shaped actuator. For a constant density fluid, cross-sectional area varies inversely with speed.

Betz's law applies to all Newtonian fluids, including wind. If all of the energy coming from wind movement through a turbine were extracted as useful energy, the wind speed afterward would drop to zero. If the wind stopped moving at the exit of the turbine, then no more fresh wind could get in; it would be blocked. In order to keep the wind moving through the turbine, there has to be some wind movement, however small, on the other side with some wind speed greater than zero. Betz's law shows that as air flows through a certain area, and as wind speed slows from losing energy to extraction from a turbine, the airflow must distribute to a wider area. As a result, geometry limits any turbine efficiency to a maximum of 59.3%.



Simple cartoon of two air molecules shows why wind turbines cannot actually run at 100% efficiency.

Betz limit

The **Betz limit** is the theoretical maximum efficiency for a wind turbine, conjectured by German physicist Albert Betz in 1919. Betz concluded that this value is **59.3%**, meaning that at most only 59.3% of the kinetic energy from wind can be used to spin the turbine and generate electricity. In reality, turbines cannot reach the Betz limit, and common efficiencies are in the 35-45% range.

Wind turbines work by slowing down passing wind in order to extract energy. If a wind turbine was 100% efficient, then all of the wind would have to stop completely upon contact with the turbine—which isn't possible by looking at a wind turbine (figure 1). In order to stop the wind completely, the air wouldn't move out of the way to the back of the turbine, which would prevent further air from coming in—causing the turbine to stop spinning.

HOW MUCH ENERGY DOES A WIND TURBINE PRODUCE?

Wind energy is a viable source of alternative energy that uses wind to generate electricity. It is also a form of solar energy. Many parts of the world have strong wind speeds where they can easily produce electricity, but some of the best locations for generating wind energy are mostly in remote areas. Moreover, offshore wind power has tremendous potential to produce electricity.

All over the world, wind power is considered eco-friendly, cost-saving, and energy-efficient energy. The concept of wind turbines originated more than a century ago. Later, in 1887 and 1888, wind energy generation took place in the United States and the United Kingdom. But, the new wind power was developed in 1891 in Denmark, where horizontal-axis wind turbines were built.

The amount of energy one can generate from wind depends on the wind speed, size of the turbine, and the length of the turbine blade.

To obtain wind energy, the kinetic energy of wind is used to create mechanical power. This mechanical power is transformed into electrical energy using wind energy conversion systems. At first, the wind hits a turbine's blades, causing them to rotate and turn the turbine connected to them. That changes the kinetic energy to rotational energy by moving a shaft.

Major Factors that determine how much power does a wind turbine produce

According to experts, it is estimated that a 10kW wind turbine has the potential to generate up to 10,000 kWh worth of energy per year. However, this evaluation relies on a turbine that may produce energy if it ran all the time, which won't always be possible.

The fact is that there will be days, weeks, and even months where there isn't enough wind for the turbine to produce the targeted amount of energy. It will only be able to provide a small fraction of its expected energy output. A soft and gentle breeze is not enough to power a wind turbine. Moreover, the extreme heat will render it practically useless.

The perfect way to calculate how much electricity a wind turbine produces is to multiply the air density with the mechanical efficiency of the turbine.

Here are some of the significant factors that determine how much power a wind turbine produces:

Wind Speed

Wind speed fluctuates, which has a direct impact on generating electricity and operating characteristics. There is no doubt that wind speed is one of the significant factors that determine how much power a wind turbine can produce. However, many areas don't experience the needed amount of wind to power a turbine consistently.

The US and most European countries have already begun the use of wind turbines in industrial sectors, residential areas, and for other purposes. It doesn't matter which brand or manufacturer you buy; if the weather conditions aren't favorable, then it won't generate much power.

Although, if the average wind speed increases marginally to 12 mph, then you can expect a remarkable boost in the amount of energy that's produced by the wind turbine.

Altitude

Altitude is another major factor that contributes to the amount of power a wind turbine generates. The higher you place the turbine, the more power it will generate.

For example, a wind turbine placed on a 100-foot tower will produce about 30% more energy than a wind turbine on a 60-foot tower. The numbers will automatically increase if there are no obstructions around or near the turbine, such as structures or tress.

The size of the wind turbine will determine how much electricity it can produce. Wind turbines with large rotor blades tend to generate more energy than turbines with smaller ones. While it may not seem like much of a difference, a 10-foot rotor blade can produce 58% more power than an 8-foot blade.

But, make sure to look for suitable and quality components for the wind turbine. Avoid manufacturers and brands that boast about power production while providing little to no information about the parts they use.

Efficiency Rating

Efficiency plays a vital role when assessing a wind turbine. The modern, technologically advanced wind turbines use a variety of designs intended to help them capture wind more efficiently.

It is not feasible for a turbine to convert 100 percent of wind passing through the blades into power. Due to its friction, these machines only have efficiency ratings of between 30 percent and 50 percent of rated power output.

Advantage and Disadvantage of Wind Energy

There is no doubt that wind power is one of the technological breakthroughs that might lead to more efficient energy production. While the future of wind energy seems promising, some demerits are noticeable.

Advantage

- Cost-Effective
- Renewable and Sustainable
- Clean and eco-friendly fuel source
- Creates employment
- Industrial and domestic installation

Disadvantage

- Fluctuation of wind
- Remoteness of location
- Not a profitable use of land
- Threat to wildlife
- Noise and visual pollution

Facts about Wind Turbine

Global installed wind-generation capacity offshore, and onshore has increased by the aspect of almost 75 in the past two decades. The wind power capacity has risen from 7.5 gigawatts (GW) in 1997 to some 564 GW in 2018, according to IRENA's latest data.

Wind-turbine capacity has also increased over time. In 1985, typical turbines produced a capacity of 0.05 megawatts (MW), whereas, with the advancement of technology, today's new wind power projects have increased the capabilities of about 3–5 MW offshore and 2 MW onshore. Therefore, the average capacity of wind turbines increased from 1.6 MW in 2009 to 2 MW in 2014.

According to the International Renewable Energy Agency (IRENA), the production of wind electricity in 2016 was accounted for about 16% of the electricity generated by renewables.

Many factors determine how much power a wind turbine can produce, and among all those wind speeds, efficiency, and turbine size play a significant role. Moreover, the capacity of wind turbines varies from one model or design to another. The implementation of wind energy is continuously growing, and today, about 79 countries have wind energy already in practice. Out of the 79 countries, 24 are producing more than 1,000 megawatts. This incredible renewable energy provides almost 3% of global electricity consumption.

STUDY OF WIND APPLICABLE ENERGY STANDARDS IN INDIA

India's wind energy sector is led by indigenous wind power industry and has shown consistent progress. The expansion of the wind industry has resulted in a strong ecosystem, project operation capabilities and manufacturing base of about 10,000 MW per annum. The country currently has the fourth highest wind installed capacity in the world with total installed capacity of 35.6 GW (as on 31st March 2019) and has generated around 52.66 Billion Units during 2017-18.

The Government is promoting wind power projects in entire country through private sector investment by providing various fiscal and financial incentives such as Accelerated Depreciation benefit; concessional custom duty exemption on certain components of wind electric generators. Besides, Generation Based Incentive (GBI) Scheme was available for the wind projects commissioned before 31 March 2017.

In addition to fiscal and other incentives as stated above, following steps also have been taken to promote installation of wind capacity in the country:

- Technical support including wind resource assessment and identification of potential sites through the National Institute of Wind Energy, Chennai.
- In order to facilitate inter-state sale of wind power, the inter-state transmission charges and losses have been waived off for wind and solar projects to be commissioned by March, 2022.
- Issued Guidelines for Tariff Based Competitive Bidding Process for Procurement of Power from Grid Connected Wind Power Projects with an objective 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. These Guidelines aim to enable the Distribution Licensees to procure wind power at competitive rates in a cost effective manner.

Potential of Wind Energy in India

Wind is an intermittent and site-specific resource of energy and therefore, an extensive Wind Resource Assessment is essential for the selection of potential sites. The Government, through National Institute of Wind Energy (NIWE), has installed over 800 wind-monitoring stations all over country and issued wind potential maps at 50m, 80m and 100m above ground level. The recent assessment indicates a gross wind power potential of 302 GW in the country at 100 meter above ground level. Most of this potential exists in seven windy States as given below:-

S. No.	State	Wind Potential (MW)
1	Gujarat	84431.33
2	Rajasthan	18770.49
3	Maharashtra	45394.34
4	Tamil Nadu	33799.65
5	Madhya Pradesh	10483.88
6	Karnataka	55857.36
7	Andhra Pradesh	44228.60
8	Kerala	1699.56
9	Telangana	4244.29
10	Odisha	3093.47
11	Chhattisgarh	76.59
12	West Bengal	2.08
13	Puducherry	152.83
14	Lakshadweep	7.67
15	Goa	0.84
16	Andaman & Nicobar	8.43

Total in MW	302251.49
Total in GW	302

Wind power generation capacity in India has significantly increased in recent years. As of 28 February 2021, the total installed wind power capacity was 38.789 GW, the fourth largest installed wind power capacity in the world. Wind power capacity is mainly spread across the Southern, Western and Northern regions.

Wind power costs in India are decreasing rapidly. The levelised tariff of wind power reached a record low of ₹2.43 (3.4¢ US) per kWh (without any direct or indirect subsidies) during auctions for wind projects in December 2017. However, the levelised tariff increased to ₹2.77 (3.9¢ US) per kWh in March 2021. In December 2017, union government announced the applicable guidelines for tariff-based wind power auctions to bring more clarity and minimise the risk to the developers

Installed capacity

The table below shows India's year on year installed wind power, annual wind power generation and annual growth in wind power generation since 2006.

Installed wind power capacity and generation in India since 2007															
Financial year	**06-07**	**07-08**	**08-09**	**09-10**	**10-11**	**11-12**	**12-13**	**13-14**	**14-15**	**15-16**	**16-17**	**17-18**	**18-19**[13]	**19-20**	**20-21**
Installed capacity (MW)	7,850	9,587	10,925	13,064	16,084	18,421	20,150	22,465	23,447	26,777	32,280	34,046	35,626	37,669	38,785

Generation (GWh)									28,214	28,604	46,011	52,666	62,036	64,485	59,824

Development of wind power in India began in December 1952, when Maneklal Sankalchand Thacker, a distinguished power engineer, initiated a project with the Indian Council of Scientific and Industrial Research (CSIR) to explore the possibilities of harnessing wind power in the country. The CSIR established a Wind Power Sub-Committee 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. With assistance from the 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.

In September 1954, a Symposium on Solar Energy and Wind Power organised by the CSIR and UNESCO was held in New Delhi; among the attendees was E. W. Golding, a British power engineer and authority on wind energy generation. Convinced of the potential of wind power in India, he recommended continued and extensive wind velocity surveys in different regions of India, the full-time assignment of staff to experimental wind power studies, the establishment of a dedicated research laboratory and development of small to medium-sized wind-powered electrical generators. Golding's recommendations were adopted by the CSIR in 1957. By this time, regions of Saurashtra and around Coimbatore had been identified as promising sites for generating electricity from wind power, and the Wind Power Sub-Committee had begun to erect 20 wind velocity survey stations across India, in addition to testing its indigenously designed windmills and obtaining a 6 kW. Allgaier wind turbine, which was presented to India by the West German government; experiments at Porbandar with the latter had commenced by 1961. The Indian government also considered a proposal to erect over 20,000 small to medium-sized wind-powered electrical generators in rural districts, to be used for powering water pumps and supplying electricity for remotely situated structures such as lighthouses.

In 1960, the CSIR established a Wind Power Division as part of the new National Aeronautical Laboratory (NAL) in Bangalore, which was founded that year. From the 1960s into the 1980s, the NAL and other groups continued to carry out wind velocity surveys and develop improved estimates of India's wind energy capacity. Large-scale development of wind power began in 1985 with the first wind project in Veraval, Gujarat, in the form of a 40-kW Dutch machine (make Polenko) connected to the grid. The project, an initiative of late Dr. K S Rao, the then Director of GEDA (Gujarat Energy Development Agency), was a joint venture between GEDA and J K Synthetics Ltd. Though the performance of this machine was quite poor, it established the technical viability of operating wind turbines in the grid-connected mode in India. Subsequently, the Government of India planned several demonstration wind farms in the coastal regions of the country and simultaneously launched a massive programme to identify sites suitable for wind projects. In 1986, demonstration wind farms were set up in the coastal areas of Maharashtra (Ratnagiri), Gujarat (Okha) and Tamil Nadu (Tirunelveli) with 55 kW Vestas wind turbines. These demonstration projects were supported by the Ministry of New and Renewable Energy (MNRE). The demonstration projects set up in 1985-86 established beyond doubt, both the technical and economic viability of the wind energy projects, while the wind-mapping programme resulted in the identification of many sites suitable for wind power projects (C-WET 2001; Mani 1990, 1992, 1994; Mani and Mooley 1983).

The potential for wind farms in the country was first assessed in 2011 to be more than 2,000 GW by Prof. Jami Hossain of TERI University, New Delhi. This was subsequently re-validated by Lawrence Berkley National Laboratory, US (LBNL) in an independent study in 2012. As a result, the MNRE set up a committee to reassess the potential[18] and through the National Institute of Wind Energy (NIWE, previously C-WET) has announced a revised estimation of the potential wind resource in India from 49,130 MW to 302,000 MW assessed at 100 m hub height. Wind turbines are now being set up at even 120 m hub height and the wind resource at higher hub heights of around 120 m or more that are prevailing is possibly even more.

In 2015, the MNRE set the target for Wind Power generation capacity by the year 2022 at 60,000 MW.

East and North east regions have no grid connected wind power plant as of December 2017.

No offshore wind farm is under implementation as of December 2017. However, an Offshore Wind Policy was announced in 2015 and presently weather stations and LIDARs are being set up by NIWE at some locations. The first offshore wind farm is planned near Dhanushkodi in Tamil Nadu

Installed Wind Power Capacity

Fiscal Year End	Cumulative Capacity (in MW)
2005	6,270
2006	7,850
2007	9,587
2008	10,925
2009	13,064
2010	16,084
2011	18,421
2012	20,149
2013	21,264
2014	23,354
2015	26,769
2016	32,280
2017	34,046
2018	35,626

Electricity generation

Wind power accounts for nearly 10% of India's total installed power generation capacity and generated 62.03 TWh in the fiscal year 2018–19, which is nearly 4% of total electricity generation. The capacity utilisation factor is nearly 19.33% in the fiscal year 2018-19 (16% in 2017–18, 19.62% in 2016-17 and 14% in 2015-16). 70% of annual wind generation is during the five months duration from May to September coinciding with Southwest monsoon duration. In India, solar power is complementary to wind power as it is generated mostly during the non-monsoon period in daytime.

Monthly Electricity Generation in India April, 2018 - March, 2019

Month	North	West	South	East	North East	Total (GWh)
April 2018	552.54	1,604.27	1,165.93	-	-	3,322.74
May 2018	587.60	2,481.92	1,371.58	-	-	4,441.09
June 2018	1,035.61	3,461.16	3,827.89	12.28	-	8,336.94
July 2018	950.36	4,011.23	6,403.68	-	-	11,365.27
August 2018	910.12	3,730.76	7,129.62	1.15	-	11,771.66
September 2018	600.53	1,778.12	3,708.99	5.70	-	6,093.34
October 2018	209.39	744.69	1,864.79	3.91	-	2,789.24
November 2018	184.31	760.81	1,232.00	3.91	-	2,181.03
December 2018	283.01	1,333.62	1,163.33	9.29	-	2,789.24
January 2019	312.56	1,233.13	1,296.29	9.91	-	2,851.89
February 2019	385.01	1,313.14	1,384.07	12.25	-	3,094.47
March 2019	392.77	1,477.50	1,083.57	12.10	-	2,965.93
Total (GWh)	6,403.79	23,930.36	31,631.72	70.50	-	62,036.38

Wind power by state

Tamil Nadu

Tamil Nadu's wind power capacity is around 29% of India's total. The Government of Tamil Nadu realized the importance and need for renewable energy, and set up a separate Agency, as registered society, called the Tamil Nadu Energy Development Agency (TEDA) as early as 1985. Tamil Nadu is a leader in Wind Power in India. In Muppandal windfarm the total capacity is 1500 MW, the largest wind power plant in India. The total wind installed capacity in Tamil Nadu is 7633 MW.[29] During the fiscal year 2014–15, the electricity generation is 9.521 GWh, with about a 15% capacity utilization factor.

Maharashtra

Maharashtra is one of the prominent states that installed wind power projects second to Tamil Nadu in India. As of end of March 2016, installed wind power capacity is 4655.25 MW· As of now there are 50 developers registered with state nodal agency "Maharashtra energy Development Agency" for development of wind power projects. All the major manufacturers of wind turbines including ReNew Power, Suzlon, Vestas, Gamesa, Regen, Leitner Shriram have presence in Maharashtra.

Gujarat

Gujarat government's focus on tapping renewable energy has led to sharp rise in the wind power capacity in the last few years. According to official data, wind power generations capacity in the state has increased a staggering ten times in last six years. Gujarat have 16% of total capacity of country. ONGC Ltd. has installed a 51MW wind energy farm at Bhuj in Gujarat. Renewable energy projects worth a massive Rs 1 lakh crore of memorandums of understanding (MoUs) in the Vibrant Gujarat Summit in 2017.[31]

Rajasthan

4298 MW wind power plant has been installed in Rajasthan.

Madhya Pradesh

In consideration of unique concept, Govt. of Madhya Pradesh has sanctioned another 15 MW project to Madhya Pradesh Windfarms Ltd. MPWL, Bhopal at Nagda Hills near Dewas under consultation from Consolidated Energy Consultants Ltd. CECL Bhopal. All the 25 WEGs have been commissioned on 31.03.2008 and under successful operation.

Kerala

55 MW production of wind power is installed in Kerala. The first wind farm of the state was set up in 1997 at Kanjikode in Palakkad district.

The agency has identified 16 sites for setting up wind farms through private developers.

Odisha

Odisha a coastal state has higher potential for wind energy. Current installation capacity stands at 2.0 MW. Odisha has a windpower potential of 1700MW. The Govt of Odisha is actively pursuing to boost Wind power generation in the state. however it has not progressed like other states primarily because Odisha having a huge coal reserve and number of existing and upcoming thermal power plants, is a power surplus state.

West Bengal

The total installation in West Bengal is 2.10 MW till Dec 2009 at Fraserganj, Distt- South 24 Paraganas. More 0.5 MW (approx) at Ganga Sagar, Kakdwip, Distt - South 24 Paraganas. Both the project owned by West Bengal Renewable Energy Development Agency (WBREDA), Govt. of WB and project was executed on turnkey basis by Utility Powertech Limited (UPL).

Kashmir

The union territory of Ladakh and its Kargil district are potential wind energy areas, which are yet to be exploited.[19] Wind Speeds are higher during the winter months in Ladakh, which is complementary to the hydro power available during the summer months from the snow melt water. Being a Himalayan region located at higher altitude, the heating energy requirements are high which can be met by the renewable energy resources such as wind, solar and hydro power. The union territory is yet to open its account in grid connected wind power installations.

STEEL SELECTION AND DIFFERENT TYPES OF WIND TURBINE TOWER

Wind turbine towers are the response to increased demand for environmentally friendly energy. Population growth, economic development, and concerns about climate change have led to a boom in sustainable energy solutions like the wind turbine. Many types of wind turbines rely on steel for strong, safe, and effective operation. Take a look at steel-made turbines and their advantages over other materials.

The Latest Innovations in the Wind Turbine Tower Industry

Wind energy does not pollute the air or create harmful greenhouse gases. It emits no CO2, unlike fossil fuel based powers that rely on coal or natural gas combustion. Within just a few months of operation, wind turbine towers recover the energy they use during their build, operations, and dismantlement. To use wind turbines to their fullest potential, manufacturers make their main components out of steel.

Steel is strong enough to hold the turbine's blades in place as they rotate, as well as provide a strong nacelle frame and machinery. The nacelle can weigh 300 tons and requires strong steel for safe operation. The nacelle contains high-value steels such as electrical steels that help conserve energy. The wind turbine tower industry has implemented steel in most components of the turbine to provide greater strength and durability.

Tubular Steel Towers

Most large tubular steel wind turbines rely on steel for its towers, manufactured in sections of 20 to 30 meters. Each section has flanges at either end. Workers bolt these sections together on site. Tubular steel towers, as the name implies, are conical, with their diameter increasing toward the base. This increases the tower's strength and saves materials. The advantage of steel in this tower is to provide a strong enough base to support the height and the heavy weight of the turbine. Steel is also a flexible enough material to allow for the conical shape of a tubular steel tower without breaking or resisting pressure.

Lattice Towers

Lattice towers have welded steel profiles instead of steel sheets. Lattice towers provide the advantage of a smaller cost investment compared to others, since they use about half as much material as tubular towers. Yet the lattice tower still provides similar stiffness and reliability as tubular towers. Steel enables this type of wind turbine to exist using fewer materials because of the metal's incredible strength. Lattice towers allow wind to pass through the base and tower sections, decreasing the pressure and resistance on the structure. One disadvantage according to some people is the appearance of lattice towers. Aesthetic complaints have led to a marketed decrease in the use of lattice towers for modern wind turbines.

Bolted Steel Towers

The bolted steel wind turbine tower consists of several tower sections, each mounted on top of one another. These sections are made out of steel shells that workers assemble on site. The steel shells are bended steel plates, which are then bolted together with tension-controlled bolts to form the tower. Bolted steel towers allow for very tall hub heights (there is no restriction on the maximum hub height) and low transportation requirements. The towers are easy and fast to erect and require low maintenance throughout their lifetime.

Steel Hybrid Towers

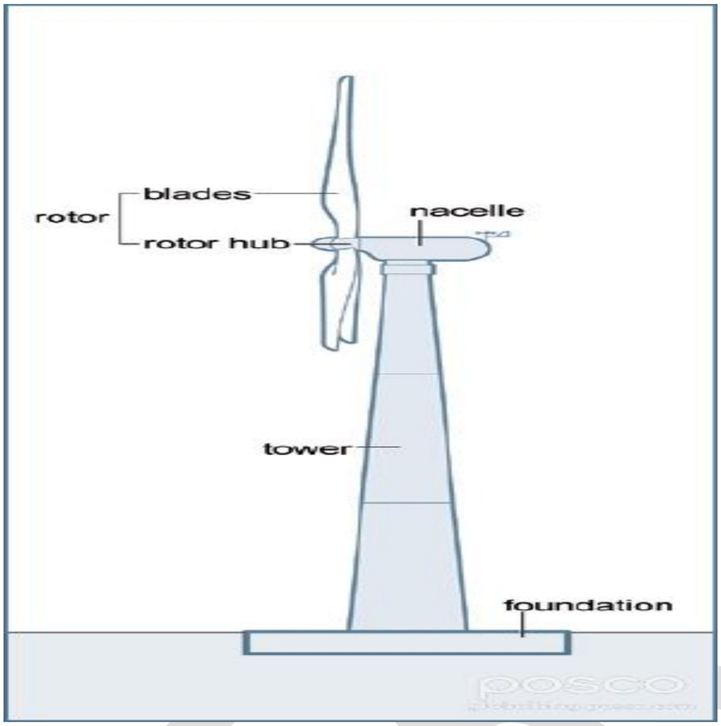
Steel and concrete hybrid towers are ideal for taller turbines, as they bring the best of both materials. Taller towers do not need as great a diameter, reducing the number of trees that must be cut down. Many experts in the industry believe that concrete-steel hybrids are the future. Concrete bottom sections with tubular steel upper sections can deliver the greatest height and stability.

Steel provides effective protection from corrosion, a strong and reliable way to seal towers, and a solution to building taller and more-efficient wind turbines.

STEEL & STRUCTURAL SOLUTIONS IN WIND POWER

While the world's population continues to grow and economies around the globe become more and more developed, demand for energy is skyrocketing. Simultaneously, climate change concerns demand that these energy solutions be sustainable. As such, the steel industry plays an important role in such production technologies, including those that generate wind power—a clean energy source that, unlike fossil fuels, does not emit carbon dioxide.

One Turbine, Many Steel Parts

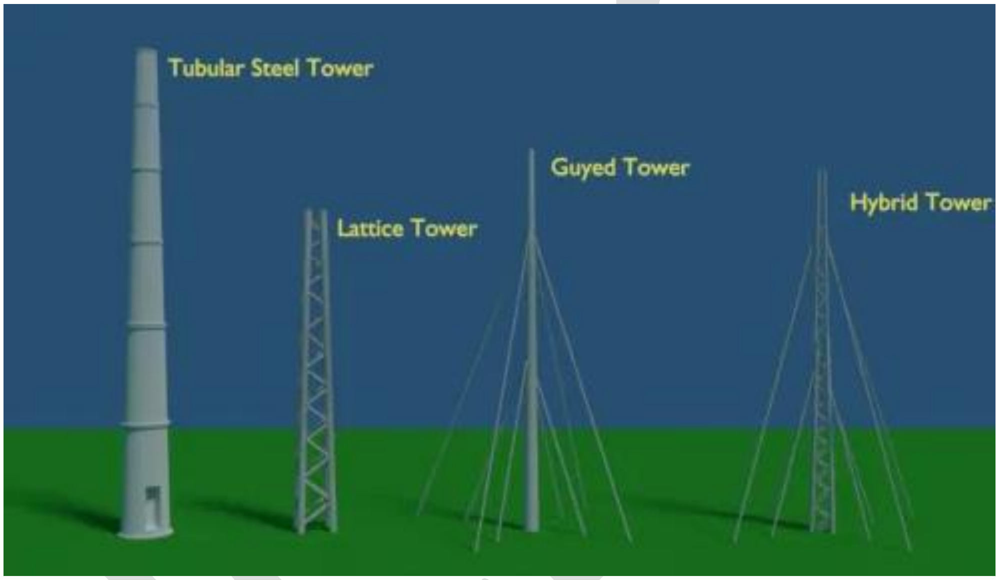


From its all-important foundation down to its screws and studs, every part of a wind turbine—machinery used to produce wind energy—depends on iron and steel. In fact, steel, on average, represents 80 percent of all the materials used to construct a wind turbine. The main components of the machine are the tower, the nacelle and the rotor. While the blades are generally made of other materials, such as carbon fiber or alloys, steel holds the turning blades in place, utilizing a cast iron or forged steel rotor hub.

At the top of the tower are the rotor and the nacelle. Because a nacelle can weigh as much as 300 tonnes, steel's strength makes it the perfect material for the nacelle's frame, housing and machinery. The nacelle contains some of the highest-value steel, including electrical steel, a specialty metal tailored to fabricate the specific magnetic properties that make wind energy feasible.

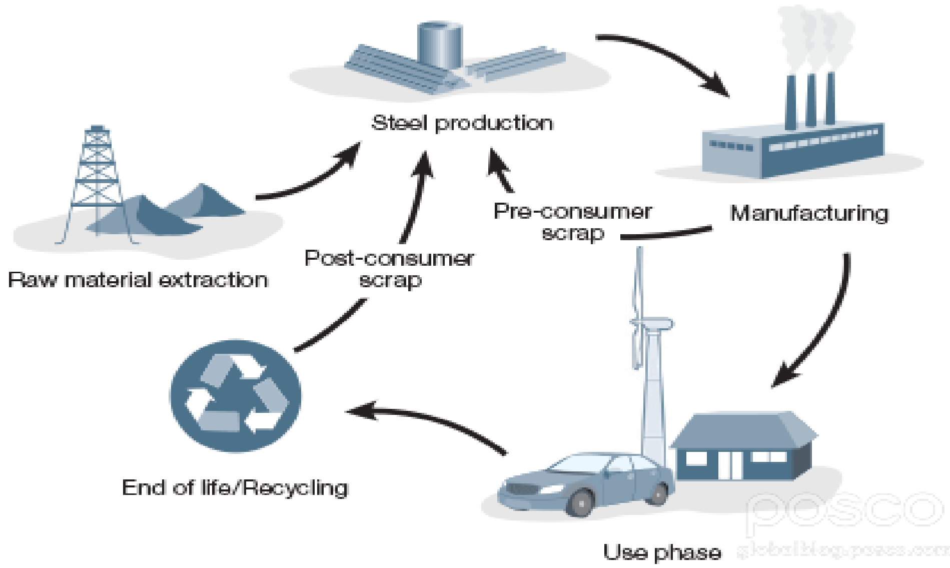
Behind the blades, a low-speed shaft transfers the rotational force of the rotor to the gearbox. Here, the gears are operated using precision tools and hardened steel components, and increase the low rotational speed of the rotor shaft to the high speed required to power the generator. Next, the mechanical energy captured by the blades is converted into electric energy, which is then directed to the transformer and converted to the higher voltage needed by the electricity grid.

Most of the steel in a wind turbine is utilized in the tower. There are a variety of towers, including steel-concrete hybrid towers, steel truss towers and steel lattice towers, but about 90 percent of all wind turbine towers are tubular steel towers. To construct one of these, fan-shaped plate segments are cut from rectangular parent steel plates and are then roll-formed and welded into cone sections. The tower and the foundation, which connects the turbine to the ground or seabed, have to be tailored to carry these heavier blades and the bigger rotor that they necessitate.



Steel-Powered Wind Energy of the Future

From a climate change and sustainability perspective, it is important to take into account the life cycle of wind turbines. Because steel is infinitely recyclable and has a limited environmental impact, it only makes sense that it is a primary material in turbine construction. The recovery of the material at the end of its useful life (which, in wind turbines, is usually 20 to 30 years) also helps to regain upfront costs, owing to the value of steel scrap. As traditional turbines age, maintenance and replacements are needed. In response to this disadvantage, new solutions are being explored to revolutionize wind energy.



Enter the EWICON (Electrostatic Wind Energy Converter)—the first ever wind energy generator that requires no blades or moving parts. Developed by researchers at Delft University of Technology in the Netherlands, the EWICON is a large rectangular-shaped steel frame that stands vertically and is made up of 40 steel tubes that run horizontally within the frame and generate charged water droplets. The droplets are discharged from the steel tubes and blown by the wind. Their movement generates power that is transferred to the electricity grid. Because the EWICON doesn't have moving parts, maintenance costs are minimal. Additionally, it doesn't make noise, vibrate or generate shadows, so it is more suitable for urban areas.

Likewise, the Dutch Wind Mill, a new project that is part of a collective effort to transform the Dutch city of Rotterdam into a clean technology city, incorporates EWICON technology and serves as another example of the ever-improving wind energy technologies.

This "Windmill of the Future" has been designed as a 174-meter-tall bladeless steel-and-glass windmill that is to be encased by 30,000 square meters of space containing apartments, a panorama restaurant and a hotel, which will all be linked together via a series of rotating observation cabins. The structure's inner ring area will be comprised of a framework of horizontal steel tubes that generate energy in a new and sustainable way.

Dubbed the Electrostatic Wind turbine, it is a giant step up from a traditional wind turbine. Not only will this structure work like an ecosystem, but it will also be entirely energy-neutral and connected to a smart grid for surplus energy. Other technological features include an interactive information layer within the glass facades of the cabins, as well as systems for water treatment for organic waste and photovoltaics. At the moment, the project is in its research and development stages, but is set for completion between 2020 and 2025.

Continued technological advancements and supportive policy measures have the ability to dramatically increase the future of wind energy development around the world. In doing so, they will provide a more sustainable energy solution to meet the changing demands of the world. Steel will continue to support both traditional wind turbines, as well as the wind energy technologies of the future.

HOW DO WIND TURBINE WORKS

Wind turbines look like airplane propellers running on the spot—spinning round but going nowhere. They're serving a very useful purpose, however. There's energy locked in wind and their giant rotors can capture some of it and turn it instantly into electricity. Have you ever stopped to wonder how wind turbines work? Let's take a closer look!

How does a turbine generate electricity?

A turbine, like the ones in a wind farm, is a machine that spins around in a moving fluid (liquid or gas) and catches some of the energy passing by. All sorts of machines use turbines, from jet engines to hydroelectric power plants and from diesel railroad locomotives to windmills. Even a child's toy windmill is a simple form of turbine.

The huge rotor blades on the front of a wind turbine are the "turbine" part. The blades have a special curved shape, similar to the airfoil wings on a plane. When wind blows past a plane's wings, it moves them upward with a force we call lift; when it blows past a turbine's blades, it spins them around instead. The wind loses some of its kinetic energy (energy of movement) and the turbine gains just as much. As you might expect, the amount of energy that a turbine makes is proportional to the area that its rotor blades sweep out; in other words, the longer the rotor blades, the more energy a turbine will generate. Obviously, faster winds help too: if the wind blows twice as quickly, there's potentially *eight* times more energy available for a turbine to harvest. That's because the energy in wind is proportional to the cube of its speed.

Wind varies all the time so the electricity produced by a single wind turbine varies as well. Linking many wind turbines together into a large farm, and linking many wind farms in different areas into a national power grid, produces a much more steady supply overall.

Head for heights! You can see just how big a wind turbine is compared to this engineer, who's standing right inside the nacelle (main unit) carrying out maintenance. Notice how the white *blades at the front connect via an axle (gray—under the engineer's feet) to the gearbox and generator behind (blue).*

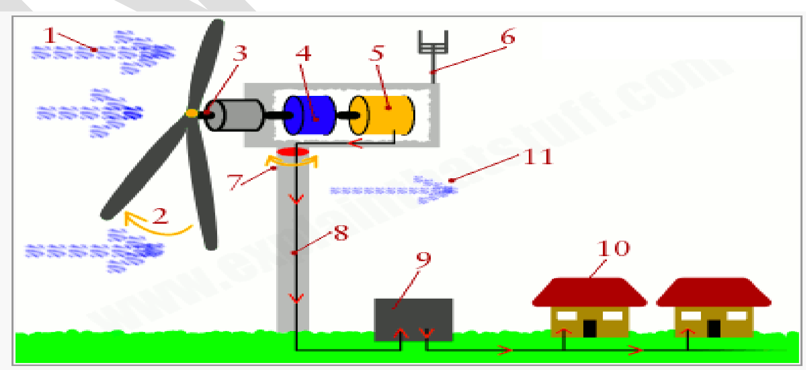
Wind varies all the time so the electricity produced by a single wind turbine varies as well. Linking many wind turbines together into a large farm, and linking many wind farms in different areas into a national power grid, produces a much more steady supply overall.

Key parts of a wind turbine?

Although we talk about "wind turbines," the turbine is only one of the parts inside these machines. For most (but not all) turbines, another key part is a **gearbox** whose gears convert the relatively slow rotation of the spinning blades into higher-speed motion—turning the drive shaft quickly enough to power the electricity generator.

The **generator** is an *essential* part of all turbines and you can think of it as being a bit like an enormous, scaled-up version of the dynamo on a bicycle. When you ride a bicycle, the dynamo touching the back wheel spins around and generates enough electricity to make a lamp light up. The same thing happens in a wind turbine, only the "dynamo" generator is driven by the turbine's rotor blades instead of by a bicycle wheel, and the "lamp" is a light in someone's home miles away. In practice, wind turbines use different types of generators that aren't very much like dynamos at all. (You can read about how they work, more generally, in our main article about generators.)

How does a wind turbine work?

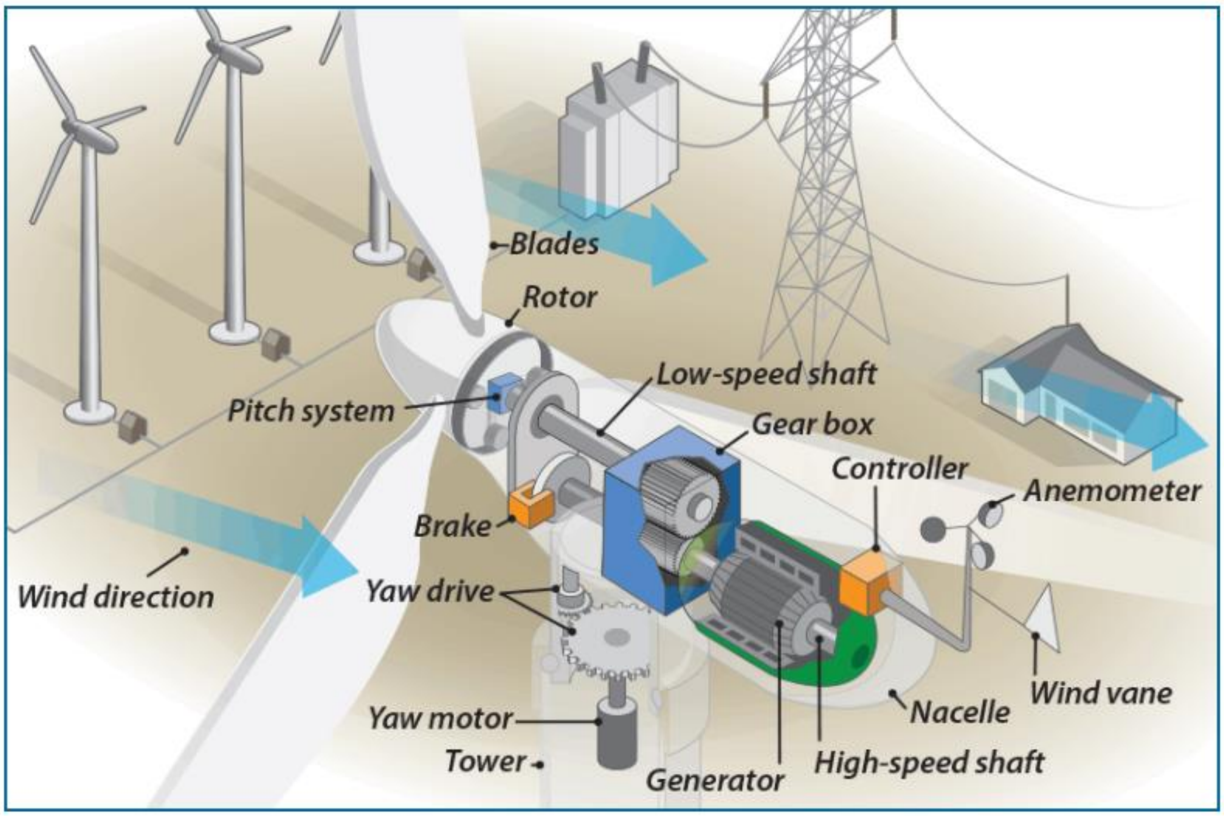


1. Wind (moving air that contains kinetic energy) blows toward the turbine's rotor blades.
2. The rotors spin around, capturing some of the kinetic energy from the wind, and turning the central drive shaft that supports them. Although the outer edges of the rotor blades move very fast, the central axle (drive shaft) they're connected to turns quite slowly.
3. In most large modern turbines, the rotor blades can swivel on the hub at the front so they meet the wind at the best angle (or "pitch") for harvesting energy. This is called the pitch control mechanism. On big turbines, small electric motors or hydraulic rams swivel the blades back and forth under precise electronic control. On smaller turbines, the pitch control is often completely mechanical. However, many turbines have fixed rotors and no pitch control at all.
4. Inside the nacelle (the main body of the turbine sitting on top of the tower and behind the blades), the gearbox converts the low-speed rotation of the drive shaft (perhaps, 16 revolutions per minute, rpm) into high-speed (perhaps, 1600 rpm) rotation fast enough to drive the generator efficiently.
5. The generator, immediately behind the gearbox, takes kinetic energy from the spinning drive shaft and turns it into electrical energy. Running at maximum capacity, a typical 2MW turbine generator will produce 2 million watts of power at about 700 volts.
6. Anemometers (automatic speed measuring devices) and wind vanes on the back of the nacelle provide measurements of the wind speed and direction.
7. Using these measurements, the entire top part of the turbine (the rotors and nacelle) can be rotated by a yaw motor, mounted between the nacelle and the tower, so it faces directly into the oncoming wind and captures the maximum amount of energy. If it's too windy or turbulent, brakes are applied to stop the rotors from turning (for safety reasons). The brakes are also applied during routine maintenance.
8. The electric current produced by the generator flows through a cable running down through the inside of the turbine tower.
9. A step-up transformer converts the electricity to about 50 times higher voltage so it can

be transmitted efficiently to the power grid (or to nearby buildings or communities). If the electricity is flowing to the grid, it's converted to an even higher voltage (130,000 volts or more) by a substation nearby, which services many turbines.

10. Homes enjoy clean, green energy: the turbine has produced no greenhouse gas emissions or pollution as it operates.

11. Wind carries on blowing past the turbine, but with less speed and energy (for reasons explained below) and more turbulence (since the turbine has disrupted its flow).



How turbines harvest maximum energy

If you've ever stood beneath a large wind turbine, you'll know that they are absolutely gigantic and mounted on incredibly high towers. The longer the rotor blades, the more energy they can capture from the wind. The giant blades (typically 70m or 230 feet in diameter, which is about 30 times the wingspan of an eagle) multiply the wind's force like a wheel and axle, so a gentle breeze is often enough to make the blades turn around. Even so, typical wind turbines stand idle about 14 percent of the time, and most of the time they don't generate maximum power. This is not a drawback, however, but a deliberate feature of their design that allows them to work very efficiently in ever-changing winds. Think of it like this. Cars don't drive around at top speed all the time: a car's engine and gearbox power the wheels as quickly or slowly as we need to go according to the speed of the traffic. Wind turbines are analogous: like cars, they're designed to work efficiently at a range of different speeds.

A typical wind turbine nacelle is 85 meters (280 feet) off the ground—that's like 50 tall adults standing on one another's shoulders! There's a good reason for this. If you've ever stood on a hill that's the tallest point for miles around, you'll know that wind travels much faster when it's clear of the buildings, trees, hills, and other obstructions at ground level. So if you put a turbine's rotor blades high in the air, they capture considerably more wind energy than they would lower down. (If you mount a wind turbine's rotor twice as high, it will usually make about a third more power.) And capturing energy is what wind turbines are all about.

Since the blades of a wind turbine are rotating, they must have kinetic energy, which they "steal" from the wind. Now it's a basic law of physics (known as the conservation of energy) that you can't make energy out of nothing, so the wind must actually slow down slightly when it passes around a wind turbine. That's not really a problem, because there's usually plenty more wind following on behind! It is a problem if you want to build a wind farm: unless you're in a really windy place, you have to make sure each turbine is a good distance from the ones around it so it's not affected by them.

This unusual Darrieus "egg-beater" wind turbine rotates about a vertical axis, unlike a normal turbine with a horizontal rotor. Its main advantage is that it can be mounted nearer to the ground, without a tower, which makes it cheaper to construct. It can also capture wind coming from any direction without using things like pitch and yaw motors, which makes it simpler and cheaper. Even so, turbines like this suffer from a variety of other problems and are quite inefficient at capturing energy, so they're very rare.

Advantages and disadvantages of wind turbines

Drawbacks

At first sight, it's hard to imagine why anyone would object to clean and green wind turbines—especially when you compare them to dirty coal-fired plants and risky nuclear ones, but they do have some disadvantages.

One of the characteristics of a wind turbine is that it doesn't generate anything like as much power as a conventional coal, gas, or nuclear plant. A typical modern turbine has a maximum power output of about 2 megawatts (MW), which is enough to run 1000 2kW electric toasters simultaneously—and enough to supply about 1000 homes, if it produces energy about 30 percent of the time. The world's biggest offshore wind turbines can now make 13 megawatts, since winds are stronger and more persistent out at sea, and power about 6500 homes. In theory, you'd need

1000 2MW turbines to make as much power as a really sizable (2000 MW or 2GW) coal-fired power plant or a nuclear power station (either of which can generate enough power to run a million 2kW toasters at the same time); in practice, because coal and nuclear power stations produce energy fairly consistently and wind energy is variable, you'd need rather more. (If a good nuclear power plant operates at maximum capacity 90 percent of the time and a good, brand new, offshore wind farm manages to do the same 45 percent of the time, you'd need twice as many wind turbines to make up for that.) Ultimately, wind power is variable and an efficient power grid needs a predictable supply of power to meet varying demand. In practice, that means it needs a mixture of different types of energy so supply can be almost 100 percent guaranteed. Some of these will operate almost continually (like nuclear), some will produce power at peak times (like hydroelectric plants), some will raise or lower the power they make at short notice (like natural gas), and some will make power whenever they can (like wind). Wind power can't be the only form of supply—and no-one has ever pretended that.

As we've just seen, you can't jam a couple of thousand wind turbines tightly together and expect them to work effectively; they have to be spaced some distance apart (typically 3–5 rotor diameters in the "crosswind" direction, between each turbine and the ones either side, and 8–10 diameters in the "downwind" direction, between each turbine and the ones in front and behind). Put these two things together and you arrive at the biggest and most obvious disadvantage of wind power: it takes up a lot of space. If you wanted to power an entire country with wind alone (which no-one has ever seriously suggested), you'd need to cover an absolutely vast land area with turbines. You could still use almost all the land *between* the turbines for farming; a typical wind farm removes less than 5 percent of land from production (for the turbine bases, access roads, and grid connections). You could mount turbines out at sea instead, but that raises other problems and costs more. Even onshore, connecting arrays of wind turbines to the power grid is obviously a bigger hurdle than wiring up a single, equivalent power plant. Some farmers and landowners have objections to new power lines, though many earn handsome profits from renting out their land (potentially with a guaranteed income for a quarter of a century), most of which they can continue to use as before.

Advantages

On the plus side, wind turbines are clean and green: unlike coal stations, once they're constructed, they don't make the carbon dioxide emissions that are causing global warming or the sulfur dioxide emissions that cause acid rain (a type of air pollution). Once you've built them, the energy they make is limitless and (except for spare parts and maintenance) free over a typical lifetime of 25 years. That's even more of an advantage than it sounds, because the cost of running conventional power plants is heavily geared to risky things like wholesale oil and gas prices and the volatility of world energy markets.

Wind turbine towers and nacelles contain quite a bit of metal, and concrete foundations to stop them falling over (a typical turbine has 8000 parts in total), so constructing them does have *some* environmental impact. Even so, looking at their entire operating lifespan, it turns out that they have among the lowest carbon dioxide emissions of any form of power generation, significantly lower than fossil-fueled plants, most solar installations, or biomass plants. Now nuclear power plants also have relatively low carbon dioxide emissions, but wind turbines don't have the security, pollution, and waste-disposal problems many people associate with nuclear energy, and they're much quicker and easier to construct. They're also much cheaper, per kilowatt hour of power they produce: half the price of nuclear and two thirds the price of coal (according to 2009 figures quoted by Milligan et al). According to the Global Wind Energy Council, a turbine can produce enough power in 3–6 months to recover the energy used throughout its lifetime (constructing, operating, and recycling it).

Pros

- Very low carbon dioxide emissions (effectively zero once constructed).
- No air or water pollution.
- No environmental impacts from mining or drilling.
- No fuel to pay for—ever!
- Completely sustainable—unlike fossil fuels, wind will never run out.

- Turbines work almost anywhere in the world where it's reliably windy, unlike fossil-fuel deposits that are concentrated only in certain regions.
- Unlike fossil-fueled power, wind energy operating costs are predictable years in advance.
- Freedom from energy prices and political volatility of oil and gas supplies from other countries.
- Wind energy prices will become increasingly competitive as fossil fuel prices rise and wind technology matures.
- New jobs in construction, operation, and manufacture of turbines.

Cons

- High up-front cost (just as for large nuclear or fossil-fueled plants).
- Economic subsidies needed to make wind energy viable (though other power forms are subsidised too, either economically or because they don't pay the economic and social cost of the pollution they make).
- Extra cost and complexity of balancing variable wind power with other forms of power.
- Extra cost of upgrading the power grid and transmission lines, though the whole system often benefits.
- Variable output—though that problem is reduced by operating wind farms in different areas and (in the case of Europe) using interconnectors between neighboring countries.
- Large overall land take—though at least 95 percent of wind farm land can still be used for farming, and offshore turbines can be built at sea.
- Can't supply 100 percent of a country's power all year round, the way fossil fuels, nuclear, hydroelectric, and biomass power can.
- Loss of jobs for people working in mining and drilling.

But what if the wind doesn't blow?

Some people worry that because wind is very variable, we might suddenly lose all our electricity and find ourselves plunged into a "blackout" (a major power outage) if we rely on it too much.

The reality of wind is quite different. "Variable" does not mean unreliable or unpredictable. Wherever you live, your power comes from a complex grid (network) of intricately interconnected power-generating units (ranging from giant power plants to individual wind turbines). Utility companies are highly adept at balancing power generated in many different places, in many different ways, to match the load (the total power demand) as it varies from hour to hour and day to day. The power from any one wind turbine will fluctuate as the wind rises and falls, but the total power produced by thousands of turbines, widely dispersed across an entire country, is much more regular and predictable. For a country like the UK, it's pretty much always windy somewhere. As Graham Sinden of Oxford University's Environmental Change Institute has shown, low wind speeds affect more than half the country for only 10 percent of the time; for 60 percent of the time, only 20 percent of the UK suffers from low wind speeds; and only for one hour per year is 90 percent of the UK suffering low speeds (Sinden 2007, figure 7). In other words, having many wind turbines spread across many different places guarantees a reasonably steady supply of wind energy virtually all year round.

While it's true that you might need 1000 wind turbines to produce as much power as a giant coal or nuclear plant, it's also true that if a single wind turbine fails or stops turning, it causes only 1/1000th (0.1 percent) of the disruption you get when a coal or nuclear plant fails or goes offline for maintenance. It's also worth bearing in mind that wind is relatively predictable several days in advance so it's easy for power planners to take account of its variability as they figure out how to make enough power to meet expected demands.

Opponents of wind power have even suggested that it might be counter-productive, because we'd need to build extra backup coal, nuclear, biomass, or hydro plants (or some way of storing wind-generated electricity) for those times when there's not enough wind blowing. That would certainly be true if we made *all* our energy from one, single mega-sized wind turbine—but we don't! In reality, even countries that have large supplies of wind energy have plenty of other sources of power too; as long as wind power is making less than half of a country's total energy, the variability of the wind is not a problem. (Denmark, for example, makes 20 percent of its electricity—and meets 43 percent of its peak load—with wind

How can we store the power of the wind?

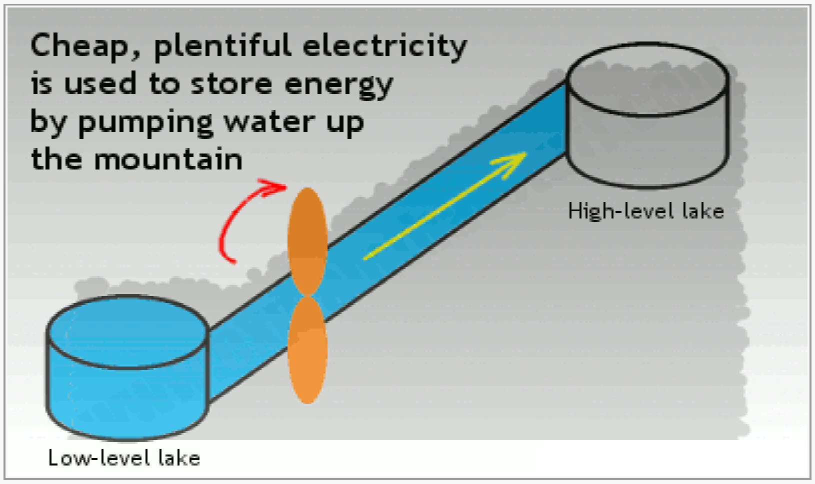


Photo: How pumped storage works: When there's lots of cheap electricity about (at night or when the wind is blowing), water is pumped up the mountain to the high-level lake at low cost. When electricity is more expensive and valuable (in the day, at peak times), the water drains from the high lake to the low one, powering a hydroelectric turbine.

Wind could play a bigger part in the future if we could find cost-effective ways of storing electricity produced on windy days for times when there's little or no wind to harvest. One tried and tested possibility is pumped storage: low-price electricity is used to pump huge amounts of water up a mountain to a high-level lake, ready to be drained back down the mountain, through a hydroelectric turbine, at times of high demand when the electricity is more valuable. (In effect, we store electricity as gravitational potential energy, which we can do indefinitely, and turn it back to electricity when it suits us.)

Batteries could also be a contender—if we had enough of them. There have been suggestions about using a fleet of electric cars as a giant collective battery, for exactly this purpose, but even large-scale batteries hooked up to individual wind farms could be very helpful. Statoil, for example, plans to install a huge wind-powered battery called BatWind in Scotland. Flywheels (heavy, low-friction wheels that store energy as they spin) are another possibility.

Micro-wind turbines

If small is beautiful, micro-wind turbines—tiny power generators of about 50–150 W capacity, perched on a roof or mast—should be the most attractive form of renewable energy by far. They're certainly very widely used for all kinds of portable power, typically for recharging batteries in things like yachts and canal boats, and for powering temporary traffic lights and road signs.

Some manufacturers have pushed micro-wind technology aggressively, hinting that people could make big savings on electricity bills, and benefit the environment, by putting a little turbine on their roof to feed energy into the national power grid. The reality is a bit different: micro-turbines linked to the grid do indeed bring economic and environmental benefits if they're sited in *reliably windy* areas, but they're less helpful in towns and cities where buildings make "energy harvesting" more of a challenge and there's much more turbulence from obstructions. So are micro-wind turbines really worth the investment? How do they compare with their big brothers?

How micro-wind turbines compare

These figures are simply designed to give a rough comparison of the differences between large-scale and micro-wind turbines. Bear in mind that there's a huge variety of micro-turbines.

	Large	**Micro**
Mounting	Tower roughly 80–100m (260–344ft) high.	Roof, or mast typically ~10m (30ft) high.

Rotor diameter	Up to 90m (300ft).	1–4m (3–12ft).
Energy production	1–8 megawatts (1000–8000 kilowatts).	50–40,000 watts (0.05–40 kilowatts).
Operates in wind speeds	10–55mph (16–90 km/h).	10–40mph (16–64 km/h).
Cost	$1–2 million per MW.	$500–100,000.
Provides power to	500–5500 homes.	1 home (or single site).

How to set up your own micro-wind turbine

If you want to build your own micro-wind turbine, what do you need? The first thing to bear in mind is that small wind turbines spin at dangerously high speeds, so technical skill and safety are paramount: ideally, get your turbine installed by a professional. Apart from the turbine itself, you also typically need a piece of electrical equipment called an inverter (which converts the direct-current electricity produced by the turbine's generator into alternating current you can use in your home) and appropriate electrical cabling. Your turbine will also need either a connection into the grid supply or batteries to store the energy it produces.

Photo: Although micro-wind turbines on homes have proved controversial, they definitely have their place. Here's the Rutland Windcharger from our top photo helping to charge the batteries in a go-anywhere, portable highway construction sign. It's getting help from the large flat solar panel mounted on top. This is a great example of how micro-wind turbines can be useful if you put them in the right place, at the right time.

Aside from the equipment, here are a few pointers worth bearing in mind:

- The best place to start is with a professional assessment of your site's wind potential, which involves a series of measurements with an anemometer. Remember that wind turbines generally work far better in open, rural areas than mounted on rooftops in cities.
- Don't assume it will automatically be windy enough to make the investment in a microturbine worthwhile: a recent UK study of microturbines by Encraft found a mixed picture, with good performance from the best-located turbines and the very worst performing model (embarrassingly) not even producing enough electricity to power its own electronics—in other words, using more electricity overall than it produced. Some contribution to the environment!
- Depending on where you live, you will almost certainly need planning consent for a wind turbine, so check that out carefully with your local authority first.
- Sound out your neighbors before you start spending any money: instead of turning your "local friends" into bitter enemies with your rooftop propeller, maybe you could persuade them to join you in a community green-energy venture?
- Remember that roof-mounted wind turbines could prove noisy and cause problems with

vibration.

- Don't forget that there are all kinds of other energy technologies that might give a quicker and better return on your investment and make more difference to the planet. Energy efficiency measures (such as improved heat insulation) generally give the quickest payback for least cost and make the most difference in the short-term, and solar hot water systems work very well almost anywhere. Ground-source heat pumps are also worth a look.

Types of Wind Turbines

The majority of wind turbines fall into two basic types:

HORIZONTAL-AXIS TURBINES

Horizontal-axis wind turbines are what many people picture when thinking of wind turbines.

Most commonly, they have three blades and operate "upwind," with the turbine pivoting at the top of the tower so the blades face into the wind.

VERTICAL-AXIS TURBINES

Vertical-axis wind turbines come in several varieties, including the eggbeater-style Darrieus model, named after its French inventor.

These turbines are omnidirectional, meaning they don’t need to be adjusted to point into the wind to operate.

Wind turbines can be built on land or offshore in large bodies of water like oceans and lakes. The U.S. Department of Energy is currently funding projects to facilitate offshore wind deployment in U.S. waters.

Applications of Wind Turbines

Modern wind turbines can be categorized by where they are installed and how they are connected to the grid:

LAND-BASED WIND

Land-based wind turbines range in size from 100 kilowatts to as large as several megawatts.

Larger wind turbines are more cost effective and are grouped together into wind plants, which provide bulk power to the electrical grid.

OFFSHORE WIND

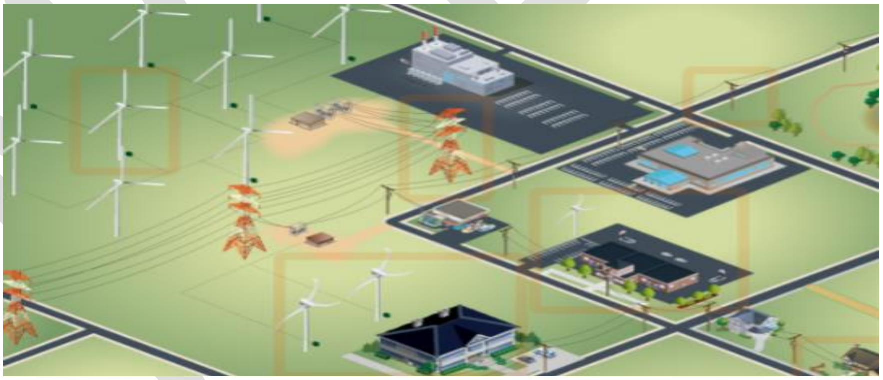
Offshore wind turbines tend to be massive, and taller than the Statue of Liberty.

They do not have the same transportation challenges of land-based wind installations, as the large components can be transported on ships instead of on roads.

These turbines are able to capture powerful ocean winds and generate vast amounts of energy.

DISTRIBUTED WIND

When wind turbines of any size are installed on the "customer" side of the electric meter, or are installed at or near the place where the energy they produce will be used, they're called "distributed wind.



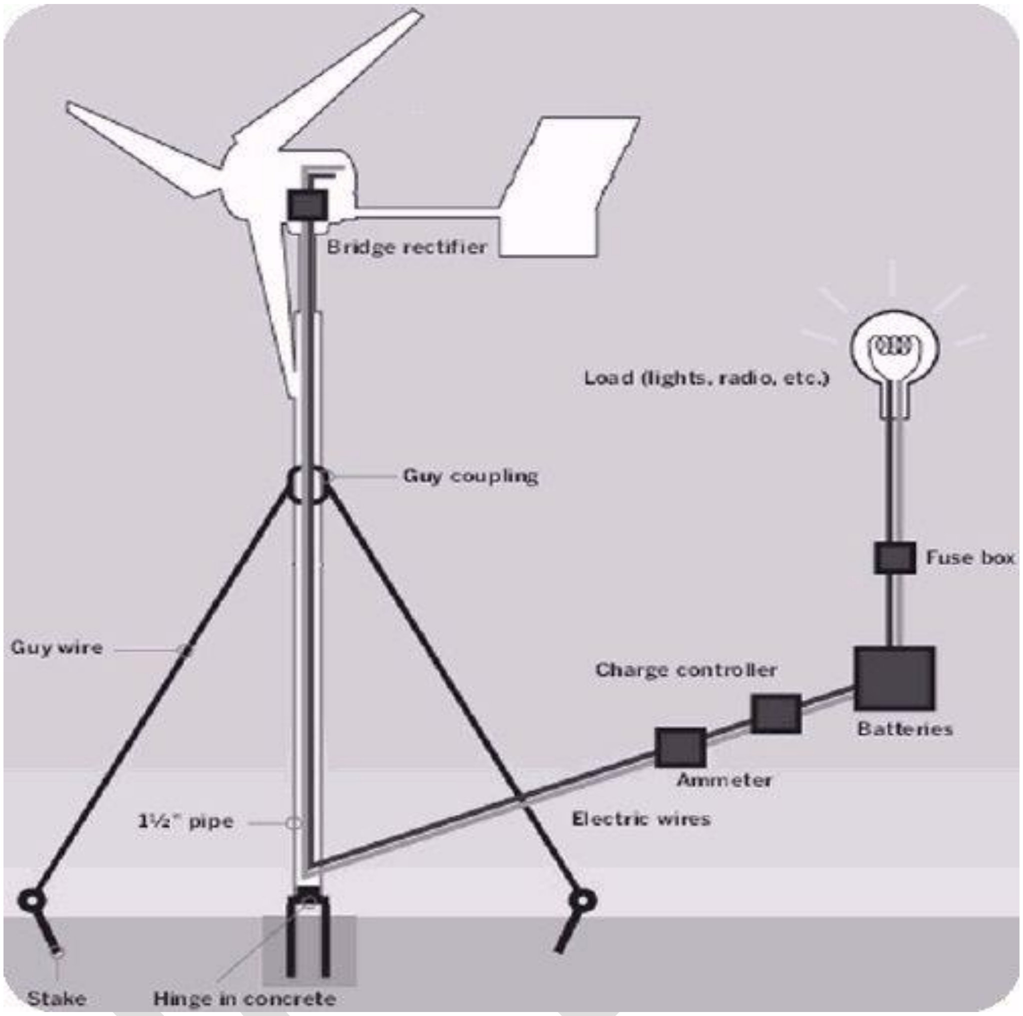
Many turbines used in distributed applications are small wind turbines. Single small wind turbines—below 100 kilowatts—are typically used for residential, agricultural, and small commercial and industrial applications.

Small turbines can be used in hybrid energy systems with other distributed energy resources, such as microgrids powered by diesel generators, batteries, and photovoltaics.

These systems are called hybrid wind systems and are typically used in remote, off-grid locations(where a connection to the utility grid is not available) and are becoming more common in grid-connected applications for resiliency.

WIND TURBINE CIRCUITS/WIRING DIAGRAM

Wind turbine wiring diagram – What's Wiring Diagram? A wiring diagram is a schematic which uses abstract pictorial symbols to demonstrate all the interconnections of components in a system. Wiring diagrams comprise two things: symbols that represent the components inside the circuit, and lines that represent the connections together. Therefore, from wiring diagrams, you understand the relative location of the ingredients and just how they may be connected. It's a language engineers need to learn after they develop projects.



What is Wind Farm and its different types ?

The word wind farm speaks for itself, for the readers who have understanding about wind turbines and wind energy. But for others, it may sound a new term. We shall take a tour on to what are wind farms, different kinds of wind farm installations etc. While going through the other articles relating to wind energy, you would have come across these terms several times. Thus for your detailed study, we shall now sink into wind farms.

Wind caused by the uneven pressure due to solar energy has the power to generate electricity when harnessed by the wind turbines. Wind turbines are machines that are located in areas where wind energy is available in abundance. Wind turbines have blades that rotate like fan to create electricity.

Wind Farms

Wind farms are those vast places on which multiple wind turbines are installed in order to harness the wind power for producing electricity. Those farms may consist of hundreds or more wind turbines, which together produce electricity. The preferred areas where those wind farms are located will be areas where wind is available on a regular and consistent basis.

These wind farms will be used not only for the installation of wind turbines, but also the space between the turbines will be used for agricultural purposes also. But it is observable that wind farms are of two types:

1. **On shore wind farms**
2. **Off shore wind farms**

On shore wind farms

On shore wind farms are those wind farms that are located on the hilly or mountain areas. Hilly and mountain areas are places that are said to have high frequency wind on a consistent basis. In order to exploit this, on shore wind farms are made. These are those wind farms on which agriculture will go hand in hand while the wind turbines produce electricity.

Off shore wind farms

Off shore wind farms are those wind farms which are located in water. That is in a sea or ocean because the speed of wind is always higher in open water than on land. Thus off shore wind farms are said to exploit more wind as the speed is always high.

Effect of wind farms on nature

As wind turbines and wind power do not emit any toxic gases nor cause any kind of air pollution and moreover uses any fuel, it does not have any ill effect on the nature. The onshore installations make it possible for the agriculture also, it saves on the land and thus no much land remains unused. While these are the positive side of wind farms, it has few negatives too.

The main negative is the slaughter of birds with the blades of wind turbines. As the number of bird slaughter is much high, it can have a direct impact on the ecological balance of nature.

Effect on human

There is no much effect on human as it does not cause any air pollution, being it the clean resource. The only side effect of it is the noise pollution that it causes. According to the studies by the United States research Council, the wind farms or the wind turbine if installed half a mile away then it shouldn't be a major issue for the humans.

It was supported by Australian studies as well, where it says that at least two kilometres distance have to be kept from the residential area to the wind farms.

Wind farms are the source where the electricity is being produced. This is mainly seen as a grid system. Though there are few drawbacks, wind energy is one of the best resource which can be used for power generation as it is the clean and free resource that is abundantly available across the globe. Besides, it is not a contributor to any air pollution. Any criticism can be kept apart by highlighting the positives since the World is under the threat of pollution and its consequences.

MODULE IV

ENERGY AUDIT AND MANAGEMENT

INTRODUCTION

Energy Audit and Its Types | Energy Management

Energy audit is an official scientific study of energy consumption of an organization /process/plant/equipment aimed at reduction of energy consumption and energy costs without affecting productivity and comforts and suggesting the methods for energy saving and reduction in energy cost. Energy audit is carried out in planned, official manner by every energy intensive organization/plant management.

i. Familiarization with the energy inlets and outlets, of energy.

ii. Data acquisition, measurements.

iii. Study of advanced, modern processes and plants for similar activities under audit.

iv. Formulating energy equations and software.

v. Economic evaluation of energy consumption in the sector/organisation/plant under audit.

vi. Analysis of energy consuming sub-processes.

vii. Suggest energy conservation processes along with alternatives, necessary investments, payback periods, economic benefits etc.

viii. Suggest steps to be taken for reducing energy consumption without sacrificing productivity.

The energy audit identifies the cost of energy and where and how it is used. It will identify the amount of energy expended in a process with the help of mass and energy balance for each process.

The energy flow diagram is then prepared showing the quantity, form, source and quality (i.e., temperature) of the energy required for various processes. Next step is to make a critical analysis for energy used and energy wasted. This is followed by identification of potential areas for energy saving.

Objectives of Energy Audit:

The main purpose of energy audit is to establish quickly and reliably, the basic relative costs of the various forms of energy purchased their main use and to identify mam locations where losses, wastages or inefficiency occurs.

In simple language we can say that, energy audit helps to understand more about the ways different energy sources are used in the industry and helps to identify areas where waste can occur and where scope for improvement may be possible. Thus, energy audit is one of the concepts used in the energy management and it involves methodological examination and comprehensive review of energy use in industries.

The Energy Audit provides the vital information base for overall energy conservation program covering essentially energy utilization analysis and evaluation of energy conservation measures. It aims at:

- Identifying the quality and cost of various energy inputs.
- Assessing present pattern of energy consumption in different cost centers of operations.
- Relating energy inputs and production output.
- Identifying potential areas of thermal and electrical energy economy.
- Highlighting wastage's in major areas.
- Fixing of energy saving potential targets for individual cost centers.
- Implementation of measures for energy conservation & realization of savings.

Need for Energy Audit

In any industry, the three top operating expenses are often found to be energy (both electrical and thermal), labour and materials. If one were to relate to the manageability of the cost or potential cost savings in each of the above components, energy would invariably emerge as a top ranker, and thus energy management function constitutes a strategic area for cost reduction. Energy Audit will help to understand more about the ways energy and fuel are used in any industry, and help in identifying the areas where waste can occur and where scope for improvement exists. The Energy Audit would give a positive orientation to the energy cost reduction, preventive maintenance and quality control programmes which are vital for production and utility activities. Such an audit programme will help to keep focus on variations which occur in the energy costs, availability and reliability of supply of energy, decide on appropriate energy mix, identify energy conservation technologies, retrofit for energy conservation equipment etc. In general, Energy Audit is the translation of conservation ideas into realities, by lending technically feasible solutions with economic and other organizational considerations within a specified time frame. The primary objective of Energy Audit is to determine ways to reduce energy consumption per unit of product output or to lower operating costs. Energy Audit provides a " bench-mark" (Reference point) for managing energy in the organization and also provides the basis for planning a more effective use of energy throughout the organization

Types of Energy Audit:

The type of Energy Audit to be performed depends on:

- Function and type of industry
- Depth to which final audit is needed, and
- Potential and magnitude of cost reduction desire

The energy audit can be of following two types:

1. Preliminary audit.

2. Detailed audit.

1. Preliminary audit:

Preliminary energy audit is a relatively quick exercise to:

• Establish energy consumption in the organization

• Estimate the scope for saving

• Identify the most likely (and the easiest areas for attention

• Identify immediate (especially no-/low-cost) improvements/ savings

• Set a 'reference point'

• Identify areas for more detailed study/measurement

• Preliminary energy audit uses existing, or easily obtained data

Preliminary audit is carried out in the limited time say within 10 days and it highlights the energy cost and wastages in the major equipment's and processes. It also gives the major energy supplies and demanding accounting. The questionnaire containing the industrial details of energy consumption process carried out, energy need to unit product; load data etc. must be completed before the pre-audit visit.

The pre-audit visit is done, by the audit team/audit consultant, in the plant area with the attention focused on the energy inputs, spots of wastage and available energy conservation opportunities. The items for waste recycling opportunities are identified. The data regarding energy inputs and outputs are collected for use during preliminary audit.

During the visit, discussions with line supervisors and line technicians and joint brainstorming may be necessary to acquire creative ideas and to know the practical difficulties in carrying out the proposed energy conservation measures (ECMs).

After the pre-audit visit, the work of energy audit is undertaken. In the preliminary audit, low tech recommendations are preferred. High tech solutions are given under detailed energy audit. Some of the low cost recommendations may be: Switching off lights when not required, replace incandescent lamps by the fluorescent lamps, automatic thermostat control, use of solar water heating panels etc.

The preliminary audit spots energy waste spots and recommend short, intermediate and long term solutions. It should adopt step by step and cautious approach for improvements and new techniques of energy management and control system.

2. Detailed (Comprehensive) Energy Audit:

Detailed energy audit, also known as comprehensive energy audit includes engineering recommendations and well defined projects with priorities. It account for the total energy utilized in plants. It involves detailed engineering for options to reduce energy consumption and also reduce cost. The duration of such studies is generally from 1 to 10 weeks. The action plan in divided into short term, medium term and long term actions.

The short term action plan requires no capital investment or least investment to avoid energy wastages and minimizing non-essential energy uses and improving the system efficiency through improved maintenance programme.

The medium term action plan requires a little investment to achieve efficiency improvement through modifications of existing equipment's and other operations.

The long term action plan is aimed to achieve economy through latest energy saving techniques and innovations. The capital investments are required to be studied thoroughly while finalizing the long term action-plan.

The comprehensive (detailed) energy audit is a thorough and extensive energy audit that analyses and quantifies the amount of energy consumption in each sub system of the plant and compares the same with the target energy consumption. Target per unit energy consumption is the optimum energy consumption per unit product.

Detailed energy auditing is carried out in three phases: Phase I, II and III.

- Phase I - Pre Audit Phase
- Phase II - Audit Phase
- Phase III - Post Audit Phase

Phase I -Pre Audit Phase

Activities A structured methodology to carry out an energy audit is necessary for efficient working. An initial study of the site should always be carried out, as the planning of the procedures necessary for an audit is most important. Initial Site Visit and Preparation Required for Detailed Auditing An initial site visit may take one day and gives the Energy Auditor/Engineer an opportunity to meet the personnel concerned, to familiarize him with the site and to assess the procedures necessary to carry out the energy audit.

During the initial site visit the Energy Auditor/Engineer should carry out the following actions: -

• Discuss with the site's senior management the aims of the energy audit.

• Discuss economic guidelines associated with the recommendations of the audit.

• Analyse the major energy consumption data with the relevant personnel.

• Obtain site drawings where available - building layout, steam distribution, compressed air distribution, electricity distribution etc.

• Tour the site accompanied by engineering/production

The main aims of this visit are: -

• To finalize Energy Audit team

• To identify the main energy consuming areas/plant items to be surveyed during the audit.

• To identify any existing instrumentation/ additional metering required.

• To decide whether any meters will have to be installed prior to the audit eg. kWh, steam, oil or gas meters.

• To identify the instrumentation required for carrying out the audit.

• To plan with time frame

• To collect macro data on plant energy resources, major energy consuming centers

• To create awareness through meetings/ programme

Step No	PLAN OF ACTION	PURPOSE / RESULTS
	Phase I –Pre Audit Phase	
Step 1	• Plan and organise • Walk through Audit • Informal Interview with Energy Manager, Production / Plant Manager	• Resource planning, Establish/organize a Energy audit team • Organize Instruments & time frame • Macro Data collection (suitable to type of industry.) • Familiarization of process/plant activities • First hand observation & Assessment of current level operation and practices
Step 2	• Conduct of brief meeting / awareness programme with all divisional heads and persons concerned (2-3 hrs.)	• Building up cooperation • Issue questionnaire for each department • Orientation, awareness creation

Phase II- Detailed Energy Audit

Activities Depending on the nature and complexity of the site, a comprehensive audit can take from several weeks to several months to complete. Detailed studies to establish, and investigate, energy and material balances for specific plant departments or items of process equipment are carried out. Whenever possible, checks of plant operations are carried out over extended periods of time, at nights and at weekends as well as during normal daytime working hours, to ensure that nothing is overlooked.

The audit report will include a description of energy inputs and product outputs by major department or by major processing function, and will evaluate the efficiency of each step of the manufacturing process. Means of improving these efficiencies will be listed, and at least a preliminary assessment of the cost of the improvements will be made to indicate the expected payback on any capital investment needed. The audit report should conclude with specific recommendations for detailed engineering studies and feasibility analyses, which must then be performed to justify the implementation of those conservation measures that require investment

The information to be collected during the detailed audit includes:

1. Energy consumption by type of energy, by department, by major items of process equip ment,

by end-use

2. Material balance data (raw materials, intermediate and final products, recycled materials, use of scrap or waste products, production of by-products for re-use in other industries, etc.)

3. Energy cost and tariff data

4. Process and material flow diagrams

5. Generation and distribution of site services (eg.compressed air, steam).

6. Sources of energy supply (e.g. electricity from the grid or self-generation)

7. Potential for fuel substitution, process modifications, and the use of co-generation systems (combined heat and power generation).

8. Energy Management procedures and energy awareness training programs within the establishment. Existing baseline information and reports are useful to get consumption pattern, production cost and productivity levels in terms of product per raw material inputs.

The audit team should collect the following baseline data:

- Technology, processes used and equipment details
- Capacity utilization
- Amount & type of input materials used
- Water consumption - Fuel Consumption
- Electrical energy consumption
- Steam consumption
- Other inputs such as compressed air, cooling water etc
- Quantity & type of wastes generated
- Percentage rejection / reprocessing
- Efficiencies / yield

Step 3	<u>Phase II –Audit Phase</u> • Primary data gathering, Process Flow Diagram, & Energy Utility Diagram	• Historic data analysis, Baseline data collection • Prepare process flow charts • All service utilities system diagram (Example: Single line power distribution diagram, water, compressed air & steam distribution. • Design, operating data and schedule of operation • Annual Energy Bill and energy consumption pattern (Refer manual, log sheet, name plate, interview)
Step 4	• Conduct survey and monitoring	• Measurements : Motor survey, Insulation, and Lighting survey with portable instruments for collection of more and accurate data. Confirm and compare operating data with design data.
Step 5	• Conduct of detailed trials /experiments for selected energy guzzlers	• Trials/Experiments: - 24 hours power monitoring (MD, PF, kWh etc.). - Load variations trends in pumps, fan compressors etc.

		- Boiler/Efficiency trials for (4 – 8 hours) - Furnace Efficiency trials Equipments Performance experiments etc
Step6	• Analysis of energy use	• Energy and Material balance & energy loss/waste analysis
Step 7	• Identification and development of Energy Conservation (ENCON) opportunities	• Identification & Consolidation ENCON measures • Conceive, develop, and refine ideas • Review the previous ideas suggested by unit personal • Review the previous ideas suggested by energy audit if any • Use brainstorming and value analysis techniques • Contact vendors for new/efficient technology
Step 8	• Cost benefit analysis	• Assess technical feasibility, economic viability and prioritization of ENCON options for implementation • Select the most promising projects • Prioritise by low, medium, long term measures
Step9	• Reporting & Presentation to the Top Management	• Documentation, Report Presentation to the top Management.

Phase III - Post Audit Phase

Step10	Phase III –Post Audit phase • Implementation and Follow-up	Assist and Implement ENCON recommendation measures and Monitor the performance • Action plan, Schedule for implementation • Follow-up and periodic review

Scope of work for detailed Energy Audit

- **Review of Electricity Bills, Contract Demand and Power Factor:** For the last one year, in which possibility will be explored for further reduction of contract demand and improvement of power factor

- **Electrical System Network :** Which would include detailed study of all the Transformer operations of various Ratings / Capacities, their operational pattern, Loading, No Load Losses, Power Factor Measurement on the Main Power Distribution Boards and scope for improvement if any. The study would also cover possible improvements in energy metering systems for better control and monitoring.
- **Study of Motors and Pumps Loading :** Study of motors (above 10 kW) in terms of measurement of voltage (V), Current (I), Power (kW) and power factor and thereby suggesting measures for energy saving like reduction in size of motors or installation of energy saving device in the existing motors. Study of Pumps and their flow, thereby suggesting measures for energy saving like reduction in size of Motors and Pumps or installation of energy saving device in the existing motors / optimization of pumps.
- **Study of Air conditioning plant :** w.r.t measurement of Specific Energy consumption i.e kW/TR of refrigeration, study of Refrigerant Compressors, Chilling Units, etc. Further, various measures would be suggested to improve its performance.
- **Cooling Tower:** This would include detailed study of the operational performance of the cooling towers through measurements of temperature differential, air/water flow rate, to enable evaluate specific performance parameters like approach, effectiveness etc.
- **Performance Evaluation of Boilers:** This includes detailed study of boiler efficiency, Thermal insulation survey and flue gas analysis./li>
- **Performance Evaluation of Turbines:** This includes detailed study of Turbine efficiency, Waste heat recovery.
- **Performance Evaluation of Air Compressor:** This includes detailed study of Air compressor system for finding its performance and specific energy consumption
- **Evaluation of Condenser performance:** This includes detailed study of condenser performance and opportunities for waste heat recovery/li>

- **Performance Evaluation of Burners / Furnace :** This includes detailed study on performance of Furnace / Burner, thermal insulation survey for finding its efficiency
- **Windows / Split Air Conditioners:** Performance shall be evaluated as regards, their input power vis-a-vis TR capacity and performance will be compared to improve to the best in the category
- **Illumination:** Study of the illumination system, LUX level in various areas, area lighting etc. and suggest measures for improvements and energy conservation opportunity wherever feasible./li>
- **DG Set:** Study the operations of DG sets to evaluate their average cost of Power Generation, Specific Energy Generation and subsequently identify areas wherein energy savings could be achieved after analysing the operational practices etc. of the DG sets

The comprehensive audit is quite exhaustive, and it is convenient to split it into following sub parts:

1. Overall system audit:

This accounts for energy leakage/loss through the total system to the atmosphere. The energy conservation measures to eliminate such leakages/loss are recommended.

2. Functional audit:

It identifies the energy conservation measures in operation and maintenance of each main plant and its subsystems and suggests ECOs is operation and maintenance.

3. Utility Audit:

It identifies yearly/monthly/daily consumption of commercial secondary energy (electricity/petroleum products/fuel etc.) and suggests ECOs.

4. Modernization audit:

It recommends major changes in the process requiring retrofitting.

Report of Energy Audit:

The comprehensive energy audit report generally converts the following:

(i) Energy conservation opportunities (ECOs)

(ii) Energy conservation measures (ECMs)

(iii) Projected investments for ECMs.

(iv) Projected annual savings of ECMs and pay-back period.

(v) Feasibility studies for retrofitting/modification work.

ENERGY MANAGEMENT AND ITS ORGANISATIONAL BACKGROUND

Energy management includes planning and operation of energy production and energy consumption units as well as energy distribution and storage. Objectives are resource conservation, climate protection and cost savings, while the users have permanent access to the energy they need. It is connected closely to environmental management, production management, logistics and other established business functions. The VDI-Guideline 4602 released a definition which includes the economic dimension: "Energy management is the proactive, organized and systematic coordination of procurement, conversion, distribution and use of energy to meet the requirements, taking into account environmental and economic objectives". It is a systematic endeavor to optmize energy efficiency for specific political, economic and or/environmental objectives through Engineering and Management techniques.

Energy management impacts on the whole organisation; to be effective as an energy manager, you need access to all parts of the organisation. But energy management has to be located somewhere. How this is resolved depends on the structure of the organisation and its maturity in terms of energy management practices.

Some points to consider are:

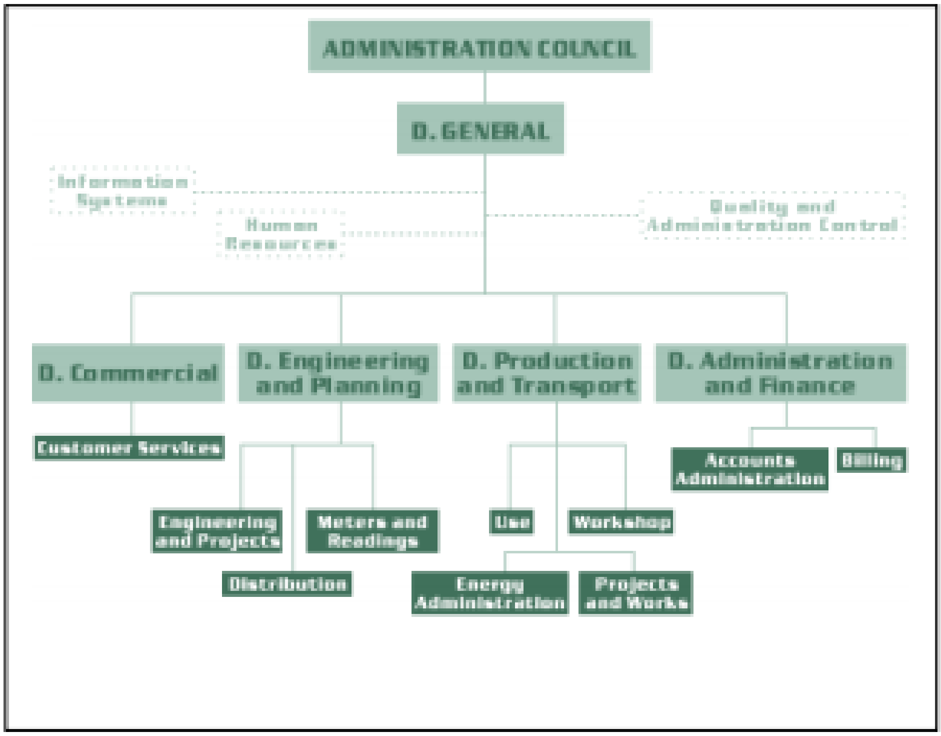
♦ Whether responsibility should be concentrated or distributed

♦ Energy management is more than a technical function—it is management too

♦ All managers are responsible in some way for energy

♦ Accountability for energy use should be distributed to those who control it.

The critical issue in organising for energy management is its integration into the overall management structure and process. While leadership may be placed in the hands of an individual or group of individuals, just like other management functions, energy management needs to be incorporated into the roles and responsibilities of all line managers.



Location of Energy Management Leadership

The energy management function, whether vested in one "energy manager or co-ordinator" or distributed among a number of middle managers, usually resides somewhere in the organisation between senior management and those who control the end-use of energy. Exactly how and where that function is placed is a decision that needs to be made in view of the existing corporate structure.

Saving energy has tended to be seen as a technical activity and you may now find yourself located in a technical section within your organisation. This may be a good base for gaining control in Phase 1 of an energy management programme but it is less appropriate for training or energy information activities.

Human Resources may be a suitable location for the motivation and training activities and a finance section may, in the long term, be a good base from which to operate the financial control and accounting procedures required in Phase 3. But both locations have disadvantages in terms of technical support and credibility.

The chief executive's office may provide the high profile and access required to kick-start energy management initially. But, in the longer term, if you want energy management to be integrated into mainstream management throughout the organization, then this may not be the best location.

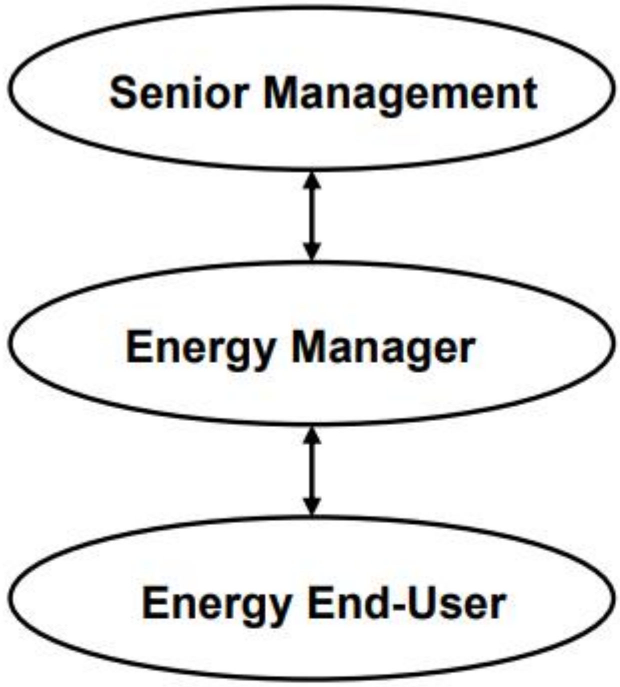


Figure : Locating Energy Management

Another option is to employ outside consultants who can provide wide experience and expertise. This may be the best option in technical situations when consultants can be used to support internal personnel but it lacks the network of relationships and day-to-day contact that is crucial for informing and motivating staff.

In practice, there may be no single ideal home for all energy management activities and the optimum location may need to reflect this, altering over time as the organization moves from one phase of its energy management programme to the next.

Each option has its own advantages and shortcomings. An important question concerns the concentration of the energy management function:

♦ Should all energy staff be kept together in a combined unit?

♦ Or is it more appropriate for them to be dispersed across the organization?

A single unit within a particular section of the organization has the shortest chain of command and it may also offer esprit de corps and economies of scale. But dispersed locations with responsibilities delegated between sections may be more useful in the longer term as a way of integrating energy management across the organization's activities.

Which of these options will prove to be best, not just in the short term but in the long run, will depend on the organization's specific circumstances. If energy management is based in a technical section, then there is a danger that 'saving energy' may be marginalized as a specialized technical activity. Energy is an organization-wide management issue, not a technical specialty. It is essential that:

♦ all managers understand that controlling energy consumption is one of their managerial responsibilities

♦ they accept and act on this 'new' understanding and are made accountable for their own energy consumption.

Top Management Support

The status and authority of the person charged with energy management responsibility is often limited. To achieve corporate objectives, those in positions of authority need to be persuaded of the need to change the ways in which their units operate. The backing of top management is needed to accomplish this. Without this endorsement from top management, energy management is likely to remain a low-level activity. As a result, it will not be accepted by mainstream managers and by their staff as something that needs to be treated as part of their everyday actions and activities.

The energy manager or co-ordinator, can increase his influence by building an alliance with a person within the organisation who holds a position of power and who will support energy management. However, influence acquired in this way is informal and transient. It is not an integral part of the organisation's energy management structure. If that person leaves or turns his or her attention elsewhere, then the influence is lost and the energy management effort may be in jeopardy.

Top management should be approached:

1. to get agreement for major spending on staff or energy measures

2. to provide a summary of progress

3. to gain recognition and prestige for energy management activities.

Roles and Responsibilities

Above all, energy management is a managerial function. It is for this reason that this Manual focuses almost entirely on management issues. Of course, the energy manager or co-ordinator must also be knowledgeable about technical concerns. Other workshops in this series provide that technical knowledge base.

Your tasks and responsibilities as energy manager are clearly wide ranging and may even vary over time as energy management becomes established. It may be helpful therefore to provide a sample job description for the role of energy manager.

Among the responsibilities often assigned to energy managers are:

1. Overseeing the formulation and implementation of an energy policy

2. Introducing and maintaining cost-effective ways of providing management information about energy consumption and attendant environmental pollution

3. Reporting such information appropriately and regularly to the staff accountable for this consumption and to senior managers

4. Introducing and maintaining efficient and environmentally benign policies and practices for the purchase and combustion of fuels

5. Raising and maintaining energy awareness throughout your organization

6. Introducing and maintaining effective 'good housekeeping' and plant operating practices

throughout your organization

7. Identifying your organization's training needs for energy-related skills and understanding

8. Identifying cost-effective opportunities for increasing energy efficiency whether in new or existing premises

9. Formulating an investment programme for reducing energy consumption and environmental pollution

10. Introducing and maintaining review procedures for establishing the value for money of energy management activities, both to top management and other relevant staff.

Function	Responsible Person				
	Director	Mgr A	Mgr B	Asst. C	Asst. D
Measure consumption	▲		■		●
Identify energy cost centres			▲	✸	■
Track performance					
Set targets for energy usage					
Develop conservation programme	▲	■		●	
Inspect equipment					
Select projects for improvement					
Allocate budget and resources					
Prepare documentation					
Provide training					
Review new projects for energy efficiency					
Carry out energy management audits					

Key: ▲ Approval Authority ■ Responsible for Work ●Perform Work ✸ Provide Technical Support

Figure : Roles and Responsibilities Matrix

ENERGY MANAGEMENT MOTIVATION

The role of the corporate energy manager is arguably one of the most challenging in the company. This person is challenged to deliver results that equal or beat the best in the industry in terms of energy costs, energy reliability, and environmental performance. A company's energy manager can be a key contributor to its competitive edge. The start of a new year seemed to be an opportune moment to explore some of the leadership and motivation challenges faced by energy managers.

Most corporate energy managers have very small teams and are often a team of one. The keys for them to deliver high levels of energy performance demanded are well known. It starts with consistent senior management sponsorship that unequivocally signals to the entire organization support for breakthrough energy performance. Like safety, this must be a message that remains visible and consistent year after year. The energy message must also be the same, irrespective of the audience.

All too often, the energy manager is faced with a wide range of mixed signals from leadership. Public commitments to energy performance may be less committed to in smaller meetings. Energy may be the passion of an individual leader, but fail to be embraced by other senior management colleagues. It does not take an organization long to pick up on a weak commitment, whatever the public pronouncements. Mixed messages from leadership are among the most corrosive elements to the energy manager's role.

An interesting variation on the quality of senior management sponsorship showed up in recent discussions with a business that has had an excellently run, well-resourced and effective energy management program for years. Energy had become so much a part of the background operations, leadership had begun to take it for granted. Failure to refresh the energy messages has many risks. The ongoing benefits and achievements become invisible, risking competiveness and motivation, and setting the stage for a slow, and possibly irreversible, deterioration.

Mixed signals from leadership tend to show up in ways that limit the energy management team's ability to be effective. The leadership ambiguity will almost certainly discourage ambitious new talent from joining the energy team. With changing technology and the need for a continuous stream on new ideas, failure to refresh team talents can be devastating.

Mixed signals typically result in the energy manager having performance goals that are not reflected in the goals of the operational managers in the plants and other operational organizations. This is a recipe for disaster. Without goal alignment, the energy manager's limited team will be relegated to implementing small peripheral subprojects and being toothless evangelists for energy efficiency. This is not the playground for ambitious, effective managers.

Even if goals are not entirely aligned, if the energy manager has the ability to deploy capital resources to implement key energy improvement measures, that person can at least have some voice in the overall operational improvement game. In the real world, even this weapon in the energy manager's armory is subject to the whim of extreme year-on-year volatility, biasing energy improvement measures to low-hanging fruit with very short payback times. This fails to capture sustainable energy productivity and reliability gains that are at the core of long-term competitiveness.

Flat-out management hypocrisy is the most demotivating of all. It is not unknown for companies to espouse aggressive emissions reductions goals in public and negate them in private. I have heard from energy managers with clear greenhouse gas reduction goals, being told to never mention greenhouse gases or climate change to leadership as "they don't believe in climate science." An energy manager may hear leadership exhort the importance attached to energy efficiency only to be told in private it is unimportant since it is a minor part of the overall costs and to focus on small projects that create good publicity.

The energy manager may also contribute to messaging issues. Faced with mixed signals, misaligned goals and unpredictable resources, it is easy to become cynical. This may show up in a leadership style that transmits lack of enthusiasm and doubts to the energy team and other colleagues. In effect, the energy manager has become the last link in the chain in communicating leadership ambiguity on the importance of energy.

Like all challenges, these are relatively easy to manage when they are clearly identified. Maybe one of the most important tasks for the energy manager is to recognize the risks of loss of clear leadership support and to make correcting that the highest priority. Equally, it is important for the leadership to look in the mirror and honestly assess how they position energy efficiency, reliability, and environmental impact in all their decisions and communications. An effective energy management team cannot be self-motivating forever.

INTRODUCTION TO STEAM SYSTEM

Introduction

Steam has been a popular mode of conveying energy since the industrial revolution. Steam is used for generating power and also used in process industries such as sugar, paper, fertilizer, refineries, petrochemicals, chemical, food, synthetic fibre and textiles The following characteristics of steam make it so popular and useful to the industry:

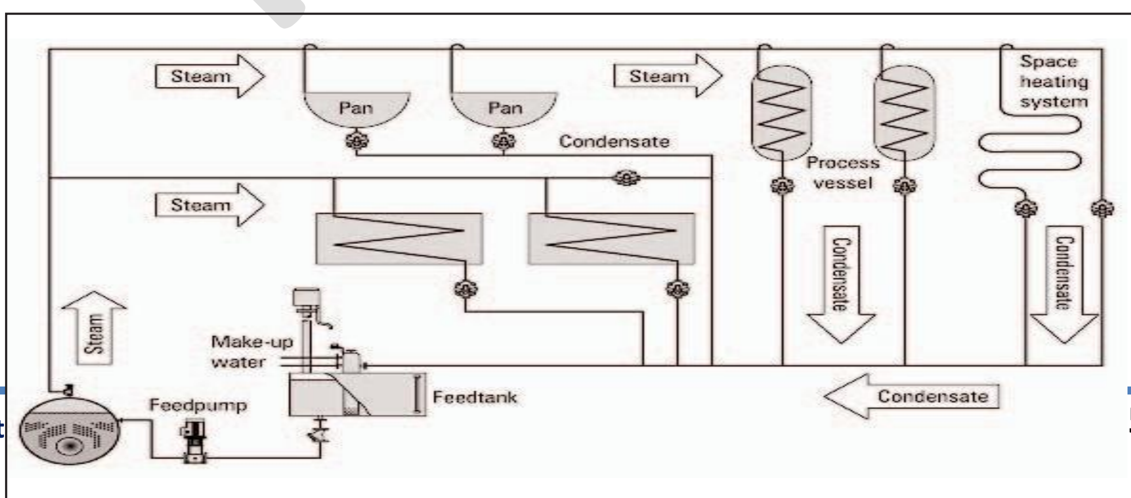
- Highest specific heat and latent heat
- Highest heat transfer coefficient
- Easy to control and distribute
- Cheap and inert

Properties of Steam

Water can exist in the form of solid, liquid and gas as ice, water and steam respectively. If heat energy is added to water, its temperature rises until a value is reached at which the water can no longer exist as a liquid. We call this the "saturation" point and with any further addition of energy, some of the water will boil off as steam. This evaporation requires relatively large amounts of energy, and while it is being added, the water and the steam released are both at the same temperature. Equally, if steam is made to release the energy that was added to evaporate it, then the steam will condense and water at same temperature will be formed.

Steam Distribution

The steam distribution system is the essential link between the steam generator and the steam user. Whatever the source, an efficient steam distribution system is essential if steam of the right quality and pressure is to be supplied, in the right quantity, to the steam using equipment. Installation and maintenance of the steam system are important issues, and must be considered at the design stage.



Steam Distribution System

As steam condenses in a process, flow is induced in the supply pipe. Condensate has a very small volume compared to the steam, and this causes a pressure drop, which causes the steam to flow through the pipes. The steam generated in the boiler must be conveyed through pipework to the point where its heat energy is required. Initially there will be one or more main pipes, or 'steam mains', which carry steam from the boiler in the general direction of the steam using plant. Smaller branch pipes can then carry the steam to the individual pieces of equipment. A typical steam distribution system is shown in Figure.

The working pressure

The distribution pressure of steam is influenced by a number of factors, but is limited by:

- The maximum safe working pressure of the boiler
- The minimum pressure required at the plant

As steam passes through the distribution pipework, it will inevitably lose pressure due to:

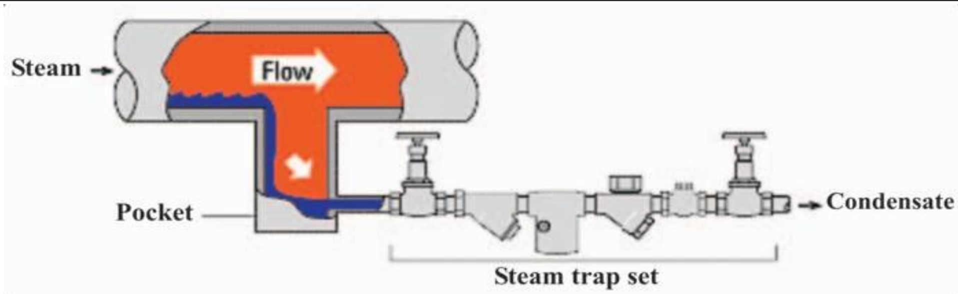
- Frictional resistance within the pipework
- Condensation within the pipework as heat is transferred to the environment.

Therefore allowance should be made for this pressure loss when deciding upon the initial distribution pressure.

Features of Steam Piping

General layout and location of steam consuming equipment is of great importance in efficient distribution of steam. Steam pipes should be laid by the shortest possible distance rather than to follow a building layout or road etc. However, this may come in the way of aesthetic design and architect's plans and a compromise may be necessary while laying new pipes.

Apart from proper sizing of pipe lines, provision must be made for proper draining of condensate which is bound to form as steam travels along the pipe.



Draining Condensate from Mains

For example, a 100 mm well lagged pipe of 30-meter length carrying steam at 7 kg/cm^2 pressure can condense nearly 10 kg. of water in the pipe in one hour unless it is removed from the pipe through traps.

The pipes should run with a fall of not less than 12.5 mm in 3 meter in the direction of flow. There should also be large pockets in the pipes to enable water to collect otherwise water will be carried along with steam. These drain pockets should be provided at every 30 to 50 meters and at any low point in the pipe network. The pocket should be fitted with a trap to discharge the condensate. Necessary expansion loops are required to take care of the expansion of pipes when they get heated up. Automatic air vents should be fixed at the dead end of steam mains, which will allow removal of air which will tend to accumulate.

Proper Selection, Operation and Maintenance of Steam Traps

The purpose of installing the steam traps is to obtain fast heating of the product and equipment by keeping the steam lines and equipment free of condensate, air and non-condensable gases. A steam trap is a valve device that discharges condensate and air from the line or piece of equipment without discharging the steam.

Functions of Steam Traps

The three important functions of steam traps are:

- To discharge condensate as soon as it is formed.

- Not to allow steam to escape.
- To be capable of discharging air and other incondensable gases.

Types of Steam Traps

There are three basic types of steam trap into which all variations fall, all three are classified by International Standard ISO 6704:1982.

Thermostatic (operated by changes in fluid temperature) - The temperature of saturated steam is determined by its pressure. In the steam space, steam gives up its enthalpy of evaporation (heat), producing condensate at steam temperature. As a result of any further heat loss, the temperature of the condensate will fall. A thermostatic trap will pass condensate when this lower temperature is sensed. As steam reaches the trap, the temperature increases and the trap close.

Mechanical (operated by changes in fluid density) - This range of steam traps operates by sensing the difference in density between steam and condensate. These steam traps include 'ball float traps' and 'inverted bucket traps'. In the 'ball float trap', the ball rises in the presence of condensate, opening a valve which passes the denser condensate. With the 'inverted bucket trap', the inverted bucket floats when steam reaches the trap and rises to shut the valve. Both are essentially 'mechanical' in their method of operation.

Thermodynamic (operated by changes in fluid dynamics) - Thermodynamic steam traps rely partly on the formation of flash steam from condensate. This group includes 'thermodynamic', 'disc', 'impulse' and 'labyrinth' steam traps.

Float and Thermostatic

The ball float type trap operates by sensing the difference in density between steam and condensate. In the case of the trap shown in Figure A, condensate reaching the trap will cause the ball float to rise, lifting the valve off its seat and releasing condensate. As can be seen, the valve is always flooded and neither steam nor air will pass through it, so early traps of this kind were vented using a manually operated cock at the top of the body. Modern traps use a thermostatic air vent, as shown in Figure B. This allows the initial air to pass whilst the trap is also handling condensate.

The automatic air vent uses the same balanced pressure capsule element as a thermostatic steam trap, and is located in the steam space above the condensate level. After releasing the initial air, it remains closed until air or other non-condensable gases accumulate during normal running and cause it to open by reducing the temperature of the air/steam mixture. The thermostatic air vent offers the added benefit of significantly increasing condensate capacity on cold start-up.

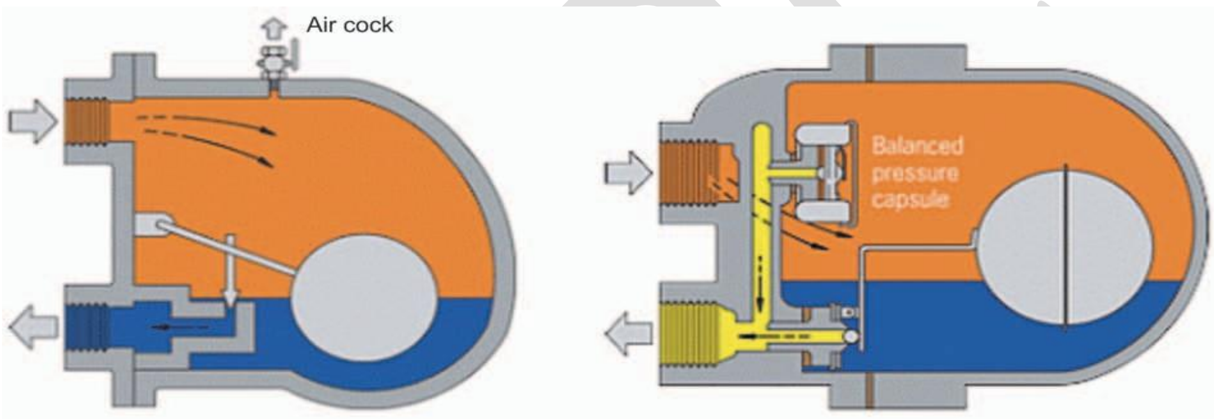


Figure A Float Trap with Air Cock **Figure B Float Trap with Thermostatic Air Vent**

In the past, the thermostatic air vent was a point of weakness if water hammer was present in the system. Even the ball could be damaged if the water hammer was severe. However, in modern float traps the air vent is a compact, very robust, all stainless steel capsule, and the modern welding techniques used on the ball makes the complete float-thermostatic steam trap very robust and reliable in water hammer situations.

In many ways the float-thermostatic trap is the closest to an ideal steam trap. It will discharge condensate as soon as it is formed, regardless of changes in steam pressure.

Advantages of the float-thermostatic steam trap

- The trap continuously discharges condensate at steam temperature. This makes it the first choice for applications where the rate of heat transfer is high for the area of heating surface available.
- It is able to handle heavy or light condensate loads equally well and is not affected by wide and sudden fluctuations of pressure or flow rate.
- As long as an automatic air vent is fitted, the trap is able to discharge air freely.
- It has a large capacity for its size.
- The versions which have a steam lock release valve are the only type of trap entirely suitable for use where steam locking can occur.
- It is resistant to water hammer.

Disadvantages of the float-thermostatic steam trap

- Although less susceptible than the inverted bucket trap, the float type trap can be damaged by severe freezing and the body should be well lagged, and / or complemented with a small supplementary thermostatic drain trap, if it is to be fitted in an exposed position.
- As with all mechanical type traps, different internals are required to allow operation over varying pressure ranges. Traps operating on higher differential pressures have smaller orifices to balance the buoyancy of the float.

ENERGY SAVING METHODS IN STEAM BOILERS

1. **Monitoring Steam Traps**

For testing a steam trap, there should be an isolating valve provided in the downstream of the trap and a test valve shall be provided in the trap discharge. When the test valve is opened, the following points have to be observed:

Condensate discharge—Inverted bucket and thermodynamic disc traps should have intermittent condensate discharge. Float and thermostatic traps should have a continuous condensate discharge. Thermostatic traps can have either continuous or intermittent discharge depending upon the load. If inverted bucket traps are used for extremely small load, it will have a continuous condensate discharge.

Flash steam—This shall not be mistaken for a steam leak through the trap. The users sometimes get confused between a flash steam and leaking steam. The flash steam and the leaking steam can be approximately identified as follows:

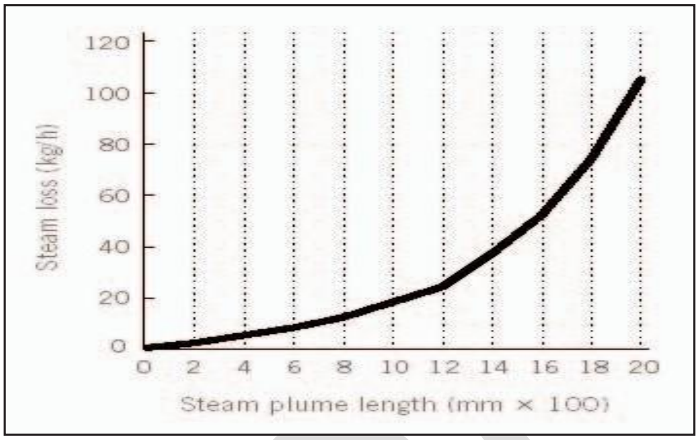
- If steam blows out continuously in a blue stream, it is a leaking steam.
- If a steam floats out intermittently in a whitish cloud, it is a flash steam.

2. **Continuous steam blow and no flow indicate, there is a problem in the trap**

Whenever a trap fails to operate and the reasons are not readily apparent, the discharge from the trap should be observed. A step-by-step analysis has to be carried out mainly with reference to lack of discharge from the trap, steam loss, continuous flow, sluggish heating, to find out whether it is a system problem or the mechanical problem in the steam trap.

3. **Avoiding Steam Leakages**

Steam leakage is a visible indicator of waste and must be avoided. It has been estimated that a 3 mm diameter hole on a pipeline carrying 7 kg/cm^2 steam would waste 33 KL of fuel oil per year. Steam leaks on high-pressure mains are prohibitively costlier than on low pressure mains. Any steam leakage must be quickly attended to. In fact, the plant should consider a regular surveillance programme for identifying leaks at pipelines, valves, flanges and joints. Indeed, by plugging all leakages, one may be surprised at the extent of fuel savings, which may reach up to 5% of the steam consumption in a small or medium scale industry or even higher in installations having several process departments.



Steam Loss vs. Plume Length

To avoid leaks it may be worthwhile considering replacement of the flanged joints which are rarely opened in old plants by welded joints. Figure provides a quick estimate for steam leakage based on plume length.

4. Providing Dry Steam for Process

The best steam for industrial process heating is the dry saturated steam. Wet steam reduces total heat in the steam. Also water forms a wet film on heat transfer and overloads traps and condensate equipment. Super-heated steam is not desirable for process heating because it gives up heat at a rate slower than the condensation heat transfer of saturated steam.

It must be remembered that a boiler without a super heater cannot deliver perfectly dry saturated steam. At best, it can deliver only 95% dry steam. The dryness fraction of steam depends on various factors, such as the level of water to be a part of the steam. Indeed, even as simple a thing as improper boiler water treatment can become a cause for wet steam.

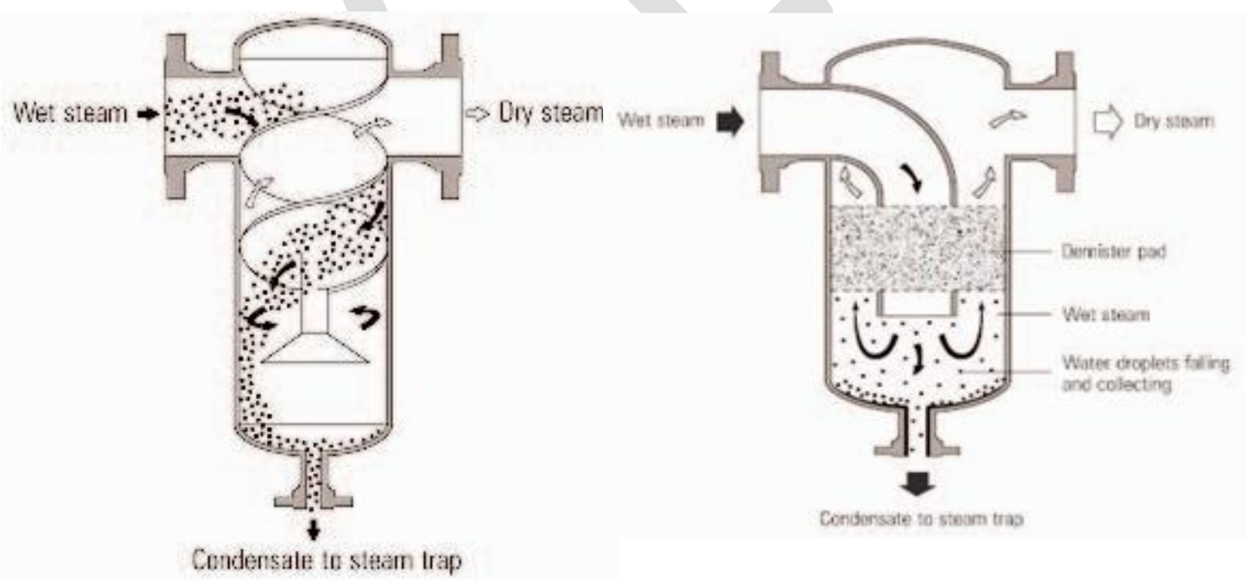
As steam flows through the pipelines, it undergoes progressive condensation due to the loss of heat to the colder surroundings, The extent of the condensation depends on the effectiveness of the lagging. For example, with poor lagging, the steam can become excessively wet.

Since dry saturated steam is required for process equipment, due attention must be paid to the boiler operation and lagging of the pipelines.

Wet steam can reduce plant productivity and product quality, and can cause damage to most items of plant and equipment. Whilst careful drainage and trapping can remove most of the water, it will not deal with the water droplets suspended in the steam. To remove these suspended water droplets, separators are installed in steam pipelines.

The steam produced in a boiler designed to generate saturated steam is inherently wet. Although the dryness fraction will vary according to the type of boiler, most shell type steam boilers will produce steam with a dryness fraction of between 95 and 98%. The water content of the steam produced by the boiler is further increased if priming and carryover occur.

A steam separator (Refer Figure 3.19) may be installed on the steam main as well as on the branch lines to reduce wetness in steam and improve the quality of the steam going to the units. By change of direction of steam, steam seperators causes the entrained water particles to be separated out and delivered to a point where they can be drained away as condensate through a conventional steam trap. A few types of separators are illustrated in the Figure below.



A cyclonic type separator

A coalescence type separator

Steam Seperators

5. Utilizing Steam at the Lowest Acceptable Pressure for the Process

A study of the steam tables would indicate that the latent heat in steam reduces as the steam pressure increases. It is only the latent heat of steam, which takes part in the heating process when applied to an indirect heating system. Thus, it is important that its value be kept as high as possible. This can only be achieved if we go in for lower steam pressures. As a guide, the steam should always be generated and distributed at the highest possible pressure, but utilized at as low a pressure as possible since it then has higher latent heat.

However, it may also be seen from the steam tables that the lower the steam pressure, the lower will be its temperature. Since temperature is the driving force for the transfer of heat at lower steam pressures, the rate of heat transfer will be slower and the processing time greater. In equipment where fixed losses are high (e.g. big drying cylinders), there may even be an increase in steam consumption at lower pressures due to increased processing time. There are, however, several equipment in certain industries where one can profitably go in for lower pressures and realize economy in steam consumption without materially affecting production time.

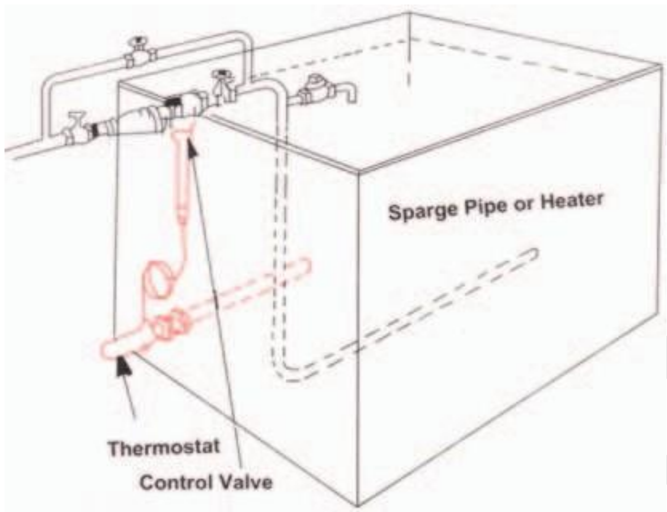
Therefore, there is a limit to the reduction of steam pressure. Depending on the equipment design, the lowest possible steam pressure with which the equipment can work should be selected without sacrificing either on production time or on steam consumption.

6. Proper Utilization of Directly Injected Steam

The heating of a liquid by direct injection of steam is often desirable. The equipment required is relatively simple, cheap and easy to maintain. No condensate recovery system is necessary. The heating is quick, and the sensible heat of the steam is also used up along with the latent heat, making the process thermally efficient. In processes where dilution is not a problem, heating is done by blowing steam into the liquid (i.e.) direct steam injection is applied. If the dilution of the tank contents and agitation are not acceptable in the process (i.e.) direct steam agitation are not acceptable, indirect steam heating is the only answer.

Ideally, the injected steam should be condensed completely as the bubbles rise through the liquid. This is possible only if the inlet steam pressures are kept very low-around 0.5 kg/cm^2

-and certainly not exceeding 1kg/cm^2. If pressures are high, the velocity of the steam bubbles will also be high and they will not get sufficient time to condense before they reach the surface. Figure 3.20 shows a recommended arrangement for direct injection of steam.



Recommended Arrangement for Directly Injected Steam

A large number of small diameter holes (2 to 5 mm), facing downwards, should be drilled on the separate pipe. This will help in dissipating the velocity of bubbles in the liquid. A thermo- static control of steam admitted is highly desirable.

7. Minimizing Heat Transfer Barriers

The metal wall may not be the only barrier in a heat transfer process. There is likely to be a film of air, condensate and scale on the steam side. On the product side there may also be baked-on product or scale, and a stagnant film of product.

Agitation of the product may eliminate the effect of the stagnant film, whilst regular cleaning on the product side should reduce the scale.

Regular cleaning of the surface on the steam side may also increase the rate of heat transfer by reducing the thickness of any layer of scale, however, this may not always be possible. This layer may also be reduced by careful attention to the correct operation of the boiler, and the removal of water droplets carrying impurities from the boiler.

Film wise Condensation

The elimination of the condensate film, is not quite as simple. As the steam condenses to give up its enthalpy of evaporation, droplets of water may form on the heat transfer surface. These may then merge together to form a continuous film of condensate. The condensate film may be between 100 and 150 times more resistant to heat transfer than a steel heating surface, and 500 to 600 times more resistant than copper.

Drop wise Condensation

If the droplets of water on the heat transfer surface do not merge immediately and no continuous condensate film is formed, 'drop wise' condensation occurs. The heat transfer rates which can be achieved during drop wise condensation are generally much higher than those achieved during film wise condensation.

8. Proper Air Venting

When steam is first admitted to a pipe after a period of shutdown, the pipe is full of air. Further amounts of air and other non-condensable gases will enter with the steam, although the proportions of these gases are normally very small compared with the steam. When the steam condenses, these gases will accumulate in pipes and heat exchangers. Precautions should be taken to discharge them. The consequence of not removing air is a lengthy warming up period, and a reduction in plant efficiency and process performance.

9. Condensate Recovery

The steam condenses after giving off its latent heat in the heating coil or the jacket of the process equipment. A sizable portion (about 25%) of the total heat in the steam leaves the process equipment as hot water. The percentage of energy in condensate to that in steam can vary from 18% at 1 bar g to 30% at 14 bar g; clearly the liquid condensate is worth reclaiming.

If this water is returned to the boiler house, it will reduce the fuel requirements of the boiler. For every 60°C rise in the feed water temperature, there will be approximately 1% saving of fuel in the boiler.

Benefits of Condensate Recovery

- Water charges are reduced.
- Effluent charges and possible cooling costs are reduced.
- Fuel costs are reduced.
- More steam can be produced from the boiler.
- Boiler blow down is reduced - less energy is lost from the boiler.
- Chemical treatment of raw make-up water is reduced.

10. Insulation of Steam Pipelines and Hot Process Equipment's

Heat can be lost due to radiation from steam pipes. As an example while lagging steam pipes, it is common to see leaving flanges uncovered. An uncovered flange is equivalent to leaving 0.6 metre of pipe line unlagged. If a 0.15 m steam pipe diameter has 5 uncovered flanges, there would be a loss of heat equivalent to wasting 5 tons of coal or 3000 litres of oil a year. This is usually done to facilitate checking the condition of flange but at the cost of considerable heat loss. The remedy is to provide easily detachable insulation covers, which can be easily removed when necessary. The various insulating materials used are cork, Glass wool, Rock wool and Asbestos.

11. Flash Steam Recovery

Flash steam is produced when condensate at a high pressure is released to a lower pressure and can be used for low pressure heating.

The higher the steam pressure and lower the flash steam pressure the greater the quantity of flash steam that can be generated. In many cases, flash steam from high pressure equipment's is made use of directly on the low pressure equipment's to reduce use of steam through pressure reducing valves.

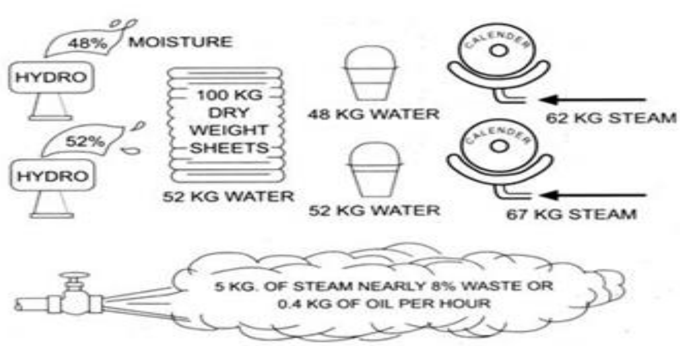
12. Reducing the Work to be done by Steam

The equipment's should be supplied with steam as dry as possible. The plant should be made efficient. For example, if any product is to be dried such as in a laundry, a press could be used to squeeze as much water as possible before being heated up in a dryer using steam.

Therefore, to take care of the above factors, automatic draining is essential and can be achieved by steam traps. The trap must drain condensate, to avoid water hammer, thermal shock and reduction in heat transfer area. The trap should also evacuate air and other non-condensable gases, as they reduce the heat transfer efficiency and also corrode the equipment. Thus, a steam trap is an automatic valve that permits passage of condensate, air and other non-condensable gases from steam mains and steam using equipment, while preventing the loss of steam in the distribution system or equipment.

The energy saving is affected by following measures:

- Reduction in operating hours
- Reduction in steam quantity required per hour
- Use of more efficient technology
- Minimizing wastage.



Steam Wastage Due to Insufficient Mechanical Drying

MODULE V

WASTE MANAGEMENT

INTRODUCTION

Waste - Sources Of Waste

We’ve had a problem with wastes ever since the industrial revolution. Technology has given rise to automation and this in turn has led to a profound effect on our environment. From non-biodegradable plastics to ozone destroying CFCs, discover how accumulation of wastes affects the planet.

The different sources of wastes can be identified by recognizing the types of wastes. Let us first define the term waste. Waste is any substance which is discarded after primary use or in other words, there is no further use for the product. We generate a huge amount of wastes in our day to day life. From the groundnut shells that we throw after eating, to the food wrappers that we discard after consuming its contents are all parts of the activities that contribute to the generation of waste.

Before discussing different sources of wastes, let us get a brief idea about various types of wastes that we generate.

Types Of Waste

In general, the wastes may be classified into the following categories:

(a) Solid wastes (b) Liquid wastes (c) Gaseous wastes

Solid wastes – These are the unwanted substances that are discarded by human society. These include urban wastes, industrial wastes, agricultural wastes, biomedical wastes and radioactive wastes.

Liquid wastes – Wastes generated from washing, flushing or manufacturing processes of industries are called liquid wastes.

Gaseous wastes – These are the wastes that are released in the form of gases from automobiles, factories or burning of fossil fuels like petroleum. They get mixed in the other gases atmosphere and occasionally cause events such as smog and acid rain.

Sources Of Wastes

Generation of waste is a part and parcel of day-to-day human life. Wastes can be generated from various sources.

This includes trash or garbage from households, schools, offices, marketplaces, restaurants and other public places. Everyday items like food debris, used plastic bags, soda cans and plastic water bottles, broken furniture, broken home appliances, clothing, etc. make up the wastes generated from such sources.

Medical or Clinical sources of wastes

Wastes produced from health care facilities, such as hospitals, clinics, surgical theaters, veterinary hospitals, and labs are referred to as medical/clinical waste. This includes surgical items, pharmaceuticals, blood, body parts, wound dressing materials, needles and syringes

Agricultural sources of wastes

Waste generated by agricultural activities, including horticulture, livestock breeding, market gardens and seedling nurseries, are called agricultural wastes. Wastes generated from this source include empty pesticide containers, old silage wrap, out of date medicines and wormers, used tires, surplus milk, cocoa pods and corn husks.

Industrial Sources of Wastes

These are the wastes released from manufacturing and processing industries like chemical plants, cement factories, power plants, textile industries, food processing industries, petroleum industries. These industries produce different types of waste products.

Wastes from Construction or Demolition

Concrete debris, wood, huge package boxes and plastics from the building materials comprise construction waste, which is yielded as a result of the construction of roads and building. Demolition of old buildings and structures also generate wastes and these are called demolition waste.

Commercial Sources

As a result of the advancement of modem cities, industries and automobiles, wastes are generated daily on a large scale from commercial enterprises. These may include food items, disposable medical items, textiles and much more.

Mining Sources

Mining activities also generate wastes that have the potential to disturb the physical, chemical and biological features of the land and atmosphere. The wastes include the overburden material, mine tailings (the waste left after extracting the ore from the rock), harmful gases released by blasting etc.

Radioactive Sources

Radioactive sources of wastes include nuclear reactors, mining of radioactive substances and atomic explosions.

Electronic sources of waste

The DVD and music players, TV, Telephones, computers, vacuum cleaners and all the other electrical stuff at your home, which are of no more use, are electronic wastes. These are also called e-waste, e-scrap, or waste electrical and electronic equipment (WEEE). Some e-waste (like TV) contains lead, mercury and cadmium, which are harmful to humans and the environment.

Types of Industrial Waste

Industrial waste can be categorized into biodegradable and non-biodegradable.

1. Biodegradable

Those industrial wastes which can be decomposed into the non-poisonous matter by the action of certain microorganisms are the biodegradable wastes. They are even comparable to house wastes. These kinds of waste are generated from food processing industries, dairy, textile mills, slaughterhouses, etc. Some examples are paper, leather, wool, animal bones, wheat, etc. They are not toxic in nature, and they do not require special treatment either. Their treatment processes include combustion, composting, gasification, bio-methanation, etc.

2. Non-biodegradable

Those industrial wastes which cannot be decomposed into non-poisonous substances are the non-biodegradable wastes. Examples are plastics, fly ash, synthetic fibres, gypsum, silver foil, glass objects, radioactive wastes, etc. They are generated by iron and steel plants, fertilizer industries, chemical, drugs, and dyes industries. It is estimated that about 10 to 15 percentage of the total industrial wastes are non-biodegradable and hazardous, and the rate of increase in this category of waste is only increasing every year. These wastes cannot be broken down easily and made less harmful.

Hence, they pollute the environment and cause threat to living organisms. They accumulate in the environment and enter the bodies of animals and plants causing diseases. However, with the advancement in technology, several disposals, and reuse methods have been developed. Wastes from one industry are being treated and utilized in another industry. For example, the cement industry uses the slag and fly ash generated as waste by steel industries. Landfill and incineration are other methods which are being resorted to, for the hazardous wastes.

MUNICIPAL WASTE MANAGEMENT

Waste is useless, unwanted or discarded material resulting from agricultural, commercial, communal and industrial activities. Municipal solid waste is term for solid waste discarded from residential and commercial establishments.

Types of Municipal Solid Wastes

There are many ways to classify solid waste.

- **Garbage:** Animal and vegetable wastes resulting from handling, sale, storage, preparation and cooking of food; contains rotting organic matter which produces an odour
- **Ashes and Residues:** Substances remaining from burning of combustible materials for cooking and heating in houses, institutions
- **Combustible and non-combustible waste:** Paper, cardboard, textile, rubber, glass, crockery, aluminium cans
- **Bulky waste:** Furniture, crates, vehicle parts, tyres, appliances such as washing machines and refrigerators
- **Street waste:** Waste collected from streets such as paper, plastic, cardboard, food scraps
- **Biodegradable and non-biodegradable waste:** Biodegradable waste refers to leftover food, vegetable and fruit peels, paper; nonbiodegradable waste refers to plastic, cans, glass, metal
- **Dead animals:** Those that die naturally or are killed on the road (does not include waste from slaughter houses)
- **Vehicles:** Abandoned in open spaces

- **Construction and demolition waste:** Stones, concrete, brick, lumber, roofing and plumbing materials, electrical wiring

Sources Of Municipal Solid Wastes

- **Residential [apartments, other dwellings]:** food scraps, vegetable peels, food packaging, cans, bottles, glass, plastics, newspapers, clothing
- **Commercial establishments [stores, office buildings, restaurants]:** Paper and cardboard, glass, plastics, packaging waste, organic waste, yard waste, hazardous waste and bulky waste
- **Institutions [schools, colleges, hospitals, government offices]:** Paper and cardboard, glass, plastics, packaging waste, organic waste, yard waste
- **Industrial [manufacturing units, treatment plants, factories]:** process waste, ash, demolition and construction waste, smoke
- **Agricultural sources [fields, orchards, vineyards, farms]:** Wastes resulting from activities such as planting and harvesting crops, prod of milk, slaughter of animals, and feedlot operations
- **Municipal [street cleaning, construction, demolition, landscaping]:** Litter, street sweepings, abandoned automobiles, construction and demolition debris
- **Open sources:** Waste from streets, alleys, parks, vacant and parking lots, playgrounds, beaches, highways

Importance of Generation Rates

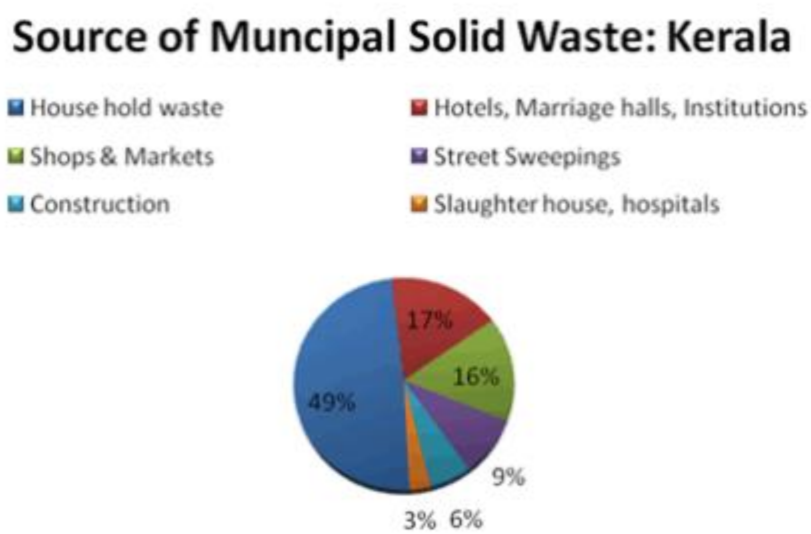
Total waste can be classified into various types according to the effective management options applied.

- **Disposed/ Collected Waste:** Solid waste materials ultimately taken to the disposal (Landfill)
- **Diverted Waste:** Solid waste materials generated but not processed through the normal waste management channels (recycled, composted etc.).

  $Generated\ Waste = Disposed\ (Collected)\ Waste + Diverted\ Waste$

The waste generation rates should be in compliance with

- ♣ State diversion requirements
- ♣ Equipment selection
- ♣ Collection and management decisions
- ♣ Design of facilities



Composition of Municipal Solid Wastes

Compostable / Bio-degradable matter = 30% - 55% (can be converted into manure)

Inert material = 40% - 45% (to go to landfill)

Recyclable materials = 5% - 10% (Recycling)

These percentages vary from city to city depending on food habits

Physical Properties of Solid Waste

♣ **Necessary for their treatment/ disposal system design Density:** Density varies depending on the composition of wastes, being higher in organic wastes and lower in commercial wastes containing mainly paper and cardboard. The density is important for selection of waste collection equipment. Usually density will increase by about 20-25 % during the transport step.

If materials are having different densities expressed as their weight fraction, the overall bulk density is calculated as follows:

$$\rho_{a+b} = \frac{(M_a + M_b)}{\left[\left(\frac{M_a}{\rho_a}\right) + \left(\frac{M_b}{\rho_b}\right)\right]}$$

Degree of volume reduction, F is the fraction remaining of the initial volume after compaction, i.e. ratio of Vc (compacted volume) to Vo (initial volume). The compaction ratio, r is defined as the ratio of the as-compacted density, ρc to the as-discarded density, ρd.

Particle Size and Distribution:

The size distribution of solid waste component is important for improving the rate of chemical reactions and for the recovery of materials.

♣ Difficult to characterize because of waste heterogeneity

♣ Important parameter for waste processing

Moisture Content:

Moisture content of solid waste is the weight loss (expressed in percent) when a sample of solid waste is dried to a constant weight at a temperature of 100 to 105oC. The % of moisture contained in a solid waste sample can be calculated on a dry or wet basis. Moisture content has a great influence on the heat of combustion as well as in the biological processes of organic matter. It depends on organic matter, weather, type of source etc. Field capacity is the moisture content retained by the mixed solids against the force of gravity. It varies with the degree of applied pressure and state of decomposition of the waste, for un-compacted wastes from residential to commercial areas, ranging from 50 to 60%.

$$Field\ Capacity, FC = 0.6 - \left[0.55 * \left(\frac{W}{4500 + W}\right)\right]$$

Where field capacity is in % dry weight, and W is the overburden weight calculated at the mid-height of the waste in lift (kg).

WASTE FILLED CONDITION	MOISTURE CONTENT (CM/CM)
WASTE AS PLACED	0.036-0.205
FIELD CAPACITY	0.3-0.4
COMPLETELY SATURATED	0.5-0.6
METHANOGENESIS AT PEAK	0.5-0.6 (by weight)

Table : Moisture content at various waste-filled conditions

Chemical Properties of Solid Wastes

Waste consists of combustible (i.e. paper) and non-combustible materials (i.e. glass). Used primarily for combustion and waste to energy (WTE) calculations but can also be used to estimate biological and chemical behaviors. Chemical properties are important for: (i) Improving leachate properties and groundwater contamination; (ii) Evaluating alternative solid waste processing and recovery options; (iii) Information about trace element composition; and (iv) Assessing the feasibility of MSW combustion directly affected by chemical composition.

Ultimate Analysis

It is defined as the total elemental analysis to determine the percentage of elements, mainly, carbon, hydrogen, oxygen, nitrogen, sulfur and present. The oxygen value is calculated by subtracting the other components, including ash and moisture, from 100%. This analysis is used to characterize the chemical composition of the organic fraction of the waste; which is turn is useful in assessing the stability of the waste as a fuel and predicting emissions from combustion

Ultimate Analysis of the Combustible Components in Household MSW

Component	% by Wt (dry basis) Carbon	Hydrogen	Oxygen	Nitrogen	Sulfur	Ash
Organic						
Paper	43.5	6.0	44.0	0.3	0.2	6.0
Plastics	60.0	7.2	22.8	—	—	10.0
Food Wastes	48.0	6.4	37.6	2.6	0.4	5.0
Yard Wastes	47.8	6.0	38.0	3.4	0.3	4.5
Textiles	55.0	6.6	31.2	4.6	0.15	2.5
Rubber	78.0	10.0	—	2.0	—	10.0
Wood	49.5	6.0	42.7	0.2	0.1	1.5
Inorganic						
Glass	0.5	0.1	0.4	<0.1	—	98.9
Metals	4.5	0.6	4.3	<0.1	—	90.5
Dirt, ash	26.3	3.0	2.0	0.5	0.2	68.0
MSW	15–30	2–5	12–24	0.2–1.0	0.02–0.1	—

Proximity Analysis

This is more specific compared to ultimate analysis, as is used to estimate the capability of the MSW as a fuel. Proximate analysis is the determination of moisture and ash content (the noncombustible components of MSW), volatile matter and fixed carbon content (good indicators of combustion capacity of MSW).

$$\textit{Fixed carbon}\ [\%] = 100\ [\%] - \textit{moisture}\ [\%] - \textit{ash}\ [\%] - \textit{volatile matter}\ [\%]$$

Typical Proximate Analysis of MSW and MSW Components

Waste Type	Proximate analysis (% by wt)			
	Moisture	Volatiles	Fixed Carbon	Noncombustable (ash)
Food mixed	70.0	21	3.6	5.0
Paper mixed	10.2	76	8.4	5.4
Newspapers	6.0	81	11.5	1.4
Cardboard	5.2	77	12.3	5.0
Plastics mixed	0.2	96	2	2
Polyethylene	0.2	98	<0.1	1.2
Polystyrene	0.2	99	0.7	0.5
PVC	0.2	87	10.8	2.1
Textiles	10	66	17.5	6.5
Yard wastes	60	30	9.5	0.5
Wood mixed	20	68	11.3	0.6
Glass	2			96–99
Metals	2.5			94–99
Domestic MSW	10–40	30–60	3–15	10–30

Heat of Combustion

The heating value of waste is a measure of the energy released when it is burned. It can be estimated by: (i) combusting samples in a boiler and measuring the heat output; (ii) using lab scale bomb calorimeter or (iii) ultimate analysis.

The heat generated from combustion in a calorimeter is:

$$U = \frac{C_v \Delta T}{M}$$

Where U is the heat value of the unknown material (cal/g), ΔT is the rise in temperature from thermo gram (0C), M is the mass of the unknown material, and Cv is the heat capacity of the calorimeter. A heating value of about 11.6 X 106 J/kg is needed to sustain combustion. The heat of combustion increases when there is more paper, cardboard and plastic in waste because they have a high heating value; and decreases when there is a high content of organic matter, and therefore, of moisture.

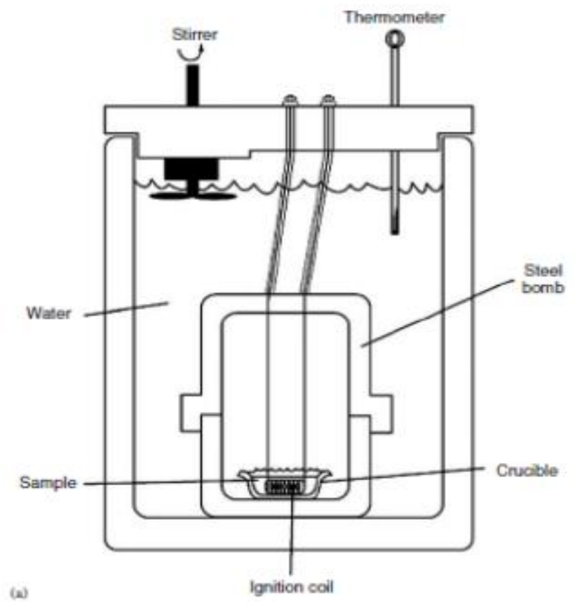


Fig. : Schematic diagram of bomb calorimeter

Fig. : Laboratory set-up of bomb calorimeter

Carbon – Nitrogen [C/N] ratio

It is the ratio of the weight of carbon to the weight of nitrogen present in compost or in materials that are being composted (preferred range: 20 – 35). Lower values indicate the loss of nitrogen as ammonium gas and render composting impractical.

Heating Value of Wastes

The heat value of waste is directly proportional to the carbon content of the waste and inversely proportional to the ash and moisture content. The heating value of wastes can be calculated by using ***Dulong's formula:***

$$HV\left(\frac{kJ}{kg}\right) = 33801[C] + 144158[H] - 0.125[O] + 9413[S]$$

Where HV is the heating value; C, H, O, S are the compositions on dry basis.

Or by using ***Modified Dulong formula***:

$$HV\left(\frac{kJ}{kg}\right) = 337[C] + 1419[H_2 - 0.125O_2] + 93[S] + 23[N]$$

Where C, H2, O2, S, and N are % by weight of each component.

Energy content from MSW as defined by Khan

$$E\left(\frac{MJ}{kg}\right) = 0.051[F + 3.6(CP)] + 0.352(PLR)$$

Where E=energy content; F=percentage weight of food in the waste; CP=percentages of cardboard and paper; and PLR=percentage of plastic, leather and rubber.

High Heat Value and Low Heat Value

Low heat value is the net heat available for combustion of the MSW, while high heat value includes the latent heat of vaporization also. These are estimated based on the chemical composition of the waste materials.

$$HHV\left(\frac{MJ}{kg}\right) = 0.339[C] + 1.44[H] - 0.139[O] + 0.105[S]$$

$$LHV\left(\frac{MJ}{kg}\right) = HHV - 0.0244 * (W + 9H)$$

Where W is percent mass of water and H is the percent of H in the waste.

Fusion Point of Ash

It is the temperature at which the ash from the combustion of waste forms clinker by fusion and agglomeration which provides information about softening and melting conditions.

Presence of Nutrients

Biological conversion via composting and biogas production depends on the essential nutrients in the waste materials as they act as substrates for the micro-organisms. According to the degree of biodegradability, the organic fraction of MSW can be classified into sugars, starches and organic acids, proteins and amino acids, hemicellulose, cellulose and lignocellulose, lignin, fats, oils, and waxes. The biodegradability of organic fraction on volatile solids basis can be expressed as: $BF = 0.83 - 0.028(LC)$, where LC is the lignin content of volatile solids as a % of dry weight.

MANAGEMENT OF SOLID WASTES

1.	Reducing quantity and toxicity of waste	4.	Composting
2.	Reusing materials	5.	Incineration with/ without energy recovery
3.	Recycling materials	6.	Sanitary landfill

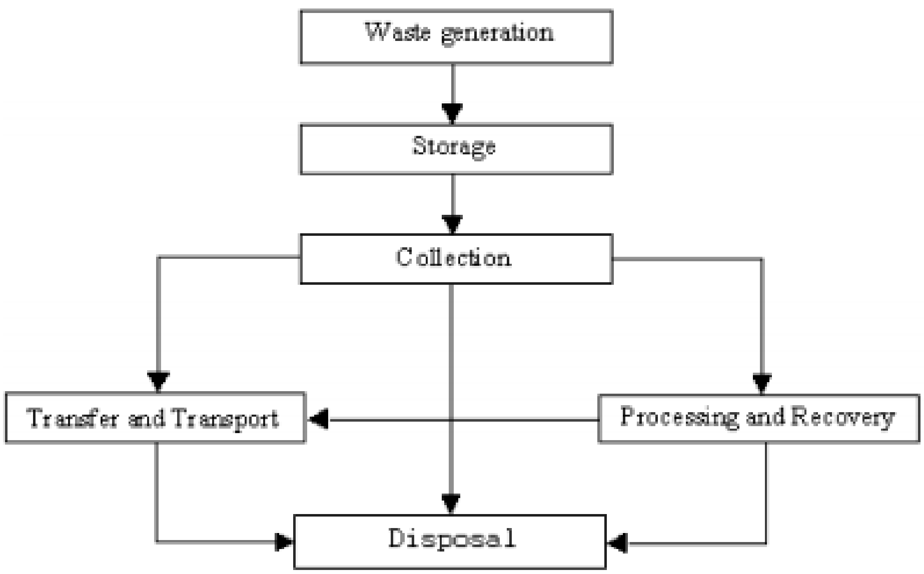


Fig. : Management of solid waste

Collection of MSW

The functional element of collection includes gathering of solid waste and recyclable materials and their transport to the location where the collection vehicle is emptied. Collection programs in different communities vary greatly depending on waste types collected, community characteristics, economics, and the desires of their residents. Data concerning waste sources, waste composition, and total volumes are critical for the proper planning of a collection program.

In India, urban bodies spend ~ Rs.500 – 1500 per ton on solid waste management, out of which 60-70% of the amount is spent on collection, 20-30% on transportation and hardly any fund on treatment and disposal.

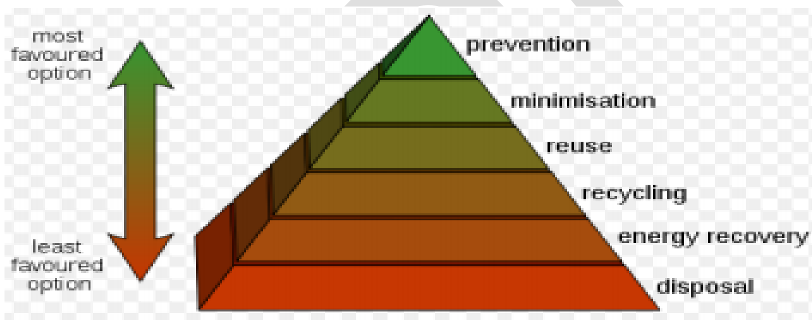


Fig. : Waste management hierarchy

On-site Handling and Storage

♣ Refers to activities associated with the handling of SW until they are placed in the containers used for storage before collection [curb collection, direct haul, transfer stations]

Factors considered for On-site Storage

♣ Types of containers used depend on characteristics of SW collected, collection frequency, and space available for the placement of containers. Residential area can have refuse bags of 7-10 L and rubbish bins of 20-30 L capacity. Container must be standardized to suit collection equipment.

♣ Location can be either at the rear of/beside the house, alleys or at the basement of apartments

♣ Public health: Waste to be removed periodically to avoid spread of diseases

♣ Aesthetics: Must be clean, shielded from public view.

Method of Collection

♣ Residential: Curb and backyard collection; set-out and set-back containers; house-to-house collection from bags

♣ Commercial – Industrial (12 m3): Large movable and stationary containers and compactors

♣ Collection frequency: For residential – everyday or once in two days, whereas for commercial/ communal – daily collection should be ensured.

♣ For food wastes, the maximum time should not exceed:

- The normal time for the accumulation of waste in the container
- Time for fresh garbage to putrefy and emit foul odour
- Length of fly-breeding cycle

Types of Collection Systems

♣ Hauled Container System: Hauled to disposal sites, emptied, and returned to original location or some other location. It can be a hoist truck, tilt frame container or trash trailer. In general, this type of system is suitable for areas with high waste generation.

♣ Stationary Container System: The container used to store waste remains at the point of generation, except when moved to curb or other location to be emptied. It can a mechanized system or manually loaded collection vehicle.

The frequency of collection depends on the type of waste, storage limitations and financial status of the agencies. It is important to allocate some places for waste collection so that residents can effectively place their wastes and the collection system will be easily routed. There should be proper collection points near urban apartment complexes for biodegradable and non-biodegradable wastes. Sometimes, transfer points are used if the destination is far from collection stations.

The collection equipment may be either automated or semi-automated. Trucks with mechanical or hydraulic lifting systems require wheeled carts. The number of collection vehicles needed for a community can be estimated by the equation

$$N = \frac{SF}{XW}$$

Where N is the number of collection vehicles needed, S the total number of households serviced, F the number of collections per week, X the number of customers a truck can service per day and W the number of workdays per week.

Proper collection routing is to be done for efficient and timely transport of the wastes. Route development is based on the scale of the area and regulations in the different municipalities.

Handling and Separation

Waste handling and separation involves the activities associated with management of waste until they are placed in a storage container for collection. Handling includes the movement of loaded containers to the point of collection. Separation of waste components is an important step in the handling and storage of solid waste at the source. The separation and processing of blended wastes usually occur at a Material Recovery Facility.

Transfer and Transport

♣ The transfer of wastes from the smaller collection vehicle to the larger transport equipment

♣ The subsequent transport of the wastes, usually over long distances, to a processing or disposal site

Transfer stations:

♣ Reduces traffic of smaller vehicles, reduces maintenance costs for collection vehicles, increases flexibility in the selection of disposal facilities, aids in recovery of recyclable materials at the transfer site, and processing of waste prior to disposing

RECYCLING:

It is important for the recovery of reusable products from waste before its final disposal. This can be done either at separation point or the waste can be brought to Material Recovery Facility (MRF). The recycling facilities should be established based on the individual materials involved, various manufacturing processes, and the nature of secondary material markets. It is important to have the wastes homogeneous and free of contamination before going to MRF. The important elements of waste that can be recycled include paper and paper products, glass, plastics, rubber, and metals like aluminium and iron products. The recycling of organic waste involves proper composting and reuse for soil conditioning and landscaping.

Recycling is probably the most ideal way of managing wasate, but it can be costly and difficult to implement. There are numerous products that can be recycled instead of thrown away including aluminum and steel cans, glass bottles, paper, and scrap metal. It is becoming more popular to complete this process and successful marketing is making recycled materials more likely to be purchased. In the long run, recycling can save money and resources as well as keep the environment cleaner.

Treatment Facilities

The importance of increased interest in mechanized facilities for waste processing is that, as MSW disposal costs rise, recycling seems to come with incentives. Hence convenient and rapid methods of separation and processing should be developed. Unit operations are designed for the separation and processing of wastes to modify the physical characteristics of the waste so that the components can be removed easily.

1. Shredding: for size reduction; done using hammer mills, flail mills, shear shredder, glass crusher and wood grinder

2. Screening: for separation of over and under-sized material – using trammel

3. Cyclone separator: for separation of light combustible materials from air stream

4. Air classification: for separation of light combustible materials from air stream

5. Magnetic separation: for separation of ferrous metal from miscellaneous waste

6. Densification: for compaction and flattening; using balers and can crushers

7. Weighing and handling facilities

Composting:

Composting is the controlled aerobic, biological conversion of organic wastes into a complex, stable final product having a number of beneficial uses, most commonly for agriculture and landscaping. Composting transforms the organic feedstock by mineralizing the simple, easily assimilable substances, i.e., protein, cellulose, sugars, and lipids to CO2 and small nitrogen compounds (e.g., nitrate) to produce a more homogeneous and stable organic product.

Different Phases:

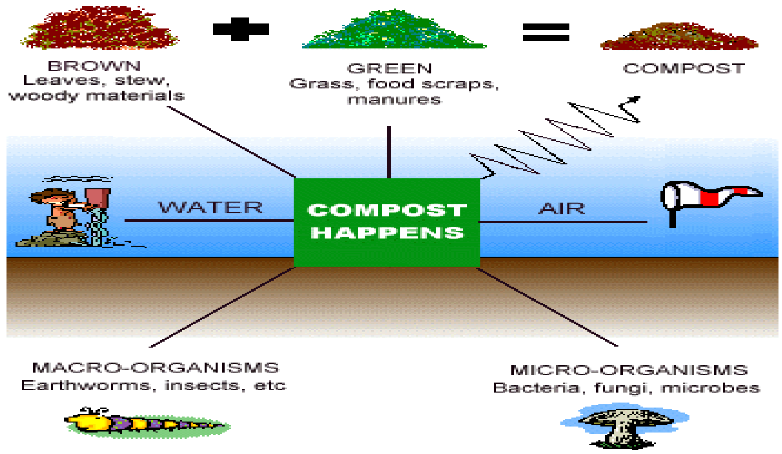
♣ Separation of inert materials (glass, plastic, metals, etc.) from the organic fraction

♣ Size reduction and chemical or biological conditioning – to enhance microbial reactions

♣ Bacterial decomposition of the raw feedstock into simpler compounds with volume reduction and heat production

♣ Stabilization and curing

Bacteria are the first to become established in the pile, processing readily decomposable substrates (e.g., proteins, carbohydrates, and sugars) faster than any other group. Nitrogen-fixing bacteria are also present in the compost pile, which will fix atmospheric N for incorporation into cellular mass. Micro-organisms such as fungi, as well as macro-organisms such as rotifers, mites, springtails, beetles and earthworms are important for the size reduction and decomposition of the compost.



Factors affecting the composting process

♣ Nutrient levels (macro- C, H, and O and micro- N, P, K, Mg, S, Fe, Ca, Mn, Zn, Cu, Co, and Mo)

♣ Nutrient balance (C/N ratio)

♣ Aeration (When acids accumulate during the early stages of composting, aeration can be done to return the compost pH to an acceptable range.)

♣ Moisture & Temperature

♣ pH (between 5.5 and 8.5)

♣ Particle size of the feedstock material

Carbon and nitrogen are required for the catabolic and anabolic processes of the microbes. A larger part of carbon substrate is oxidized to CO2 during metabolic activities and the remaining carbon is converted into cell wall or membrane, protoplasm, and storage products. The principal use of nitrogen is in the synthesis of protoplasm (proteins, amino acids, nucleic acids). The optimum C/N ratio for soil and compost microorganisms has been established at roughly 30:1. A ratio much higher than this will slow down the decomposition by oxidizing the excess carbon to CO2. If the ratio is lower than 25, composting will be inhibited due to low-energy supply and nitrogen will be lost both by leaching and volatilization as ammonia. The composting of a substrate in the presence of oxygen can be represented by the following balanced chemical reaction:

$$C_aH_bO_cN_d + 0.5(ny + 2s + r - c)O_2 \rightarrow nC_wH_xO_yN_z + sCO_2 + rH_2O + (d - nz)NH_3, \text{ where}$$

$$r = 0.5[b - nx - 3(d - nz)] \text{ and } s = a - nw.$$

$C_aH_bO_cN_d$ and $C_wH_xO_yN_z$ represent the substrate and product respectively.

Aerobic Composting

Aerobic composting is the process by which organic wastes are converted into compost or manure in presence of air. In this process, aerobic microorganisms break down organic matter and produce carbon dioxide, ammonia, water, heat and humus, the relatively stable organic end-product. Although aerobic composting may produce intermediate compounds such as organic acids, aerobic microorganisms decompose them further. The resultant compost, with its relatively unstable form of organic matter, has little risk of phytotoxicity. The heat generated accelerates the breakdown of proteins, fats and complex carbohydrates such as cellulose and hemicellulose. Hence, the processing time is shorter. Moreover, this process destroys many micro-organisms that are human or plant pathogens, as well as weed seeds, provided it undergoes sufficiently high temperature. Although more nutrients are lost from the materials by aerobic composting, it is considered more efficient and useful than anaerobic composting for agricultural production.

There are a variety of methods for aerobic composting, the most common being the Heap Method, where organic matter needs to be divided into three different types and to be placed in a heap one over the other, covered by a thin layer of soil or dry leaves. This heap needs to be mixed every week, and it takes about three weeks for conversion to take place. The process is same in the Pit Method, but carried out in specially constructed pits. Mixing has to be done every 15 days, and there is no fixed time in which the compost may be ready. Berkley Method uses a labor-intensive technique and has precise requirements of the material to be composted. Easily biodegradable materials, such as grass, vegetable matter, etc., are mixed with animal matter in the ratio of 2:1. Compost is usually ready in 15 days.

Vermicomposting

Vermicomposting is a type of composting in which certain species of earthworms are used to enhance the process of organic waste conversion and produce a better end-product. It is a mesophilic process utilizing microorganisms and earthworms. Earthworms feeds the organic waste materials and passes it through their digestive system and gives out in a granular form (cocoons) which is known as vermicompost. Earthworms consume organic wastes and reduce the volume by 40–60 percent. Each earthworm weighs about 0.5 to 0.6 gram, eats waste equivalent to its body weight and produces cast equivalent to about 50 percent of the waste it consumes in a day. The moisture content of castings ranges between 32 and 66 percent and the pH is around 7.

The level of nutrients in compost depends upon the source of the raw material and the species of earthworm. Apart from other nutrients, a fine worm cast is rich in NPK which are in readily available form and are released within a month of application. Vermicompost enhances plant growth, suppresses disease in plants, increases porosity and microbial activity in soil, and improves water retention and aeration.

INCINERATION:

Incineration is defined as the controlled burning of solid, liquid, or gaseous wastes. It is mainly done for volume reduction, and also for extending the lifetime of the land disposal facility. It operates on the principle of "waste to energy" by utilizing the energy generated for space heating and electricity generation. Aerobic combustion will result in the most complete transformation of solid waste to ash, gases, and heat energy.

The critical factors affecting the completion of the combustion are temperature, time and turbulence of the system (commonly referred to as the 3 T's). Each combustible substance has a minimum ignition temperature that must be attained in the presence of oxygen for combustion to be sustained over a definite residence period. This is to be accompanied with proper mixing of

MSW to expose maximum surface area to oxygen.

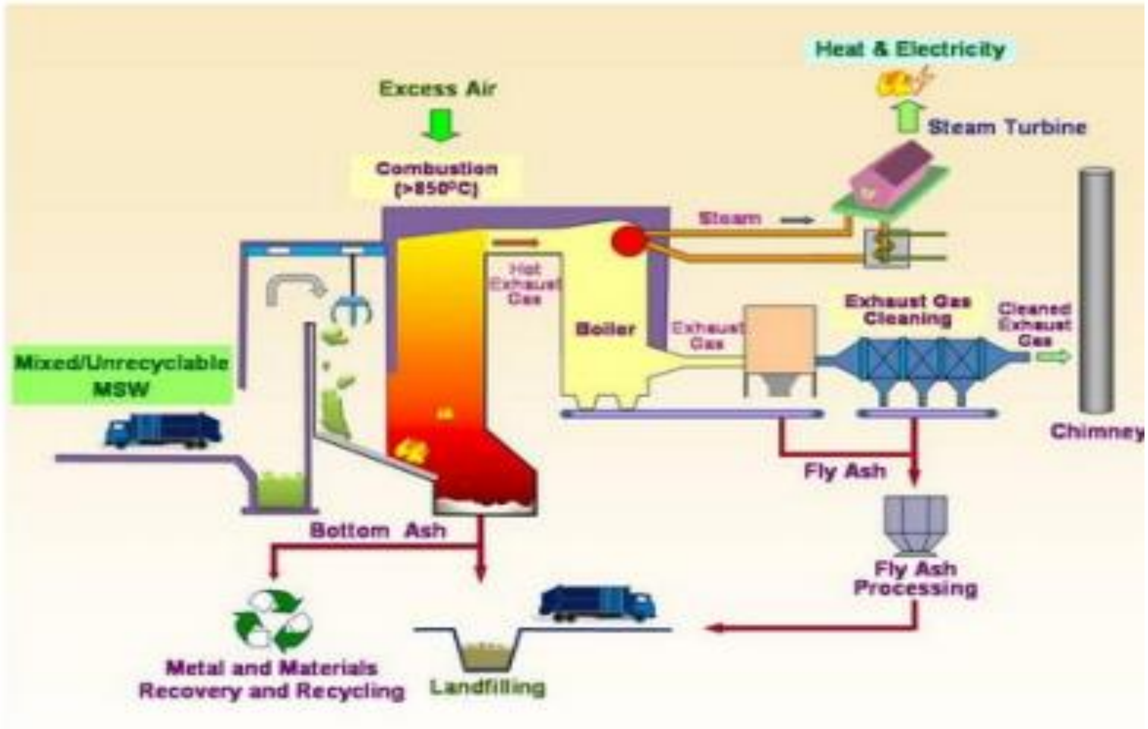


Fig. : Mass burn Incinerator

Both over-fire and under-fire air exist during the burning of the charge in the combustion chamber. The temperature of the combustion zone will vary with furnace type and is usually maintained between 815 and 1095oC. The unburned residue is carried to the end of the grates and is collected and combined with other bottom ash.

MSW can be combusted for the production of steam, which is useful for driving turbines and subsequent electricity generation. Boilers are used for the recovery and export of useful thermal energy in the form of hot water, saturated steam, or superheated steam. After passage through the boiler area, the combustion gases are freed of particulates and acid gases by electrostatic precipitators, bag-houses or mist separators and then discharged to the atmosphere.

The combustion of the organic fraction in the MSW is represented simplistically as:

$(HC)_x + O_2 \rightarrow CO_2 + H_2O + Heat$; and the complete balanced chemical reaction is given below:

$$C_aH_bO_cCl_dF_eN_fS_g + \left(a + \frac{b}{4} - \frac{c+d+e-f}{2} + g\right)O_2 \rightarrow aCO_2 + \left(\frac{b-d-e}{2}\right)H_2O + dHCl + eHF + fNO + gSO_2$$

ENVIRONMENTAL IMPACTS OF INCINERATION

The energy derived from mass burning of MSW is poor compared to a fuel due to high organic matter and moisture content. The recoverable elements are very few at this stage. Under ideal conditions, organic wastes are converted into CO2 and H2O along with the release of heat energy. The actual composition of flue gases is a function of the composition of the original MSW, furnace design, and combustion conditions.

Usually the particulates exhausted by MSW incinerators (fly ash) come within the respirable fraction. In addition, heavy metals, chlorinated dibenzo-dioxins, and other trace elements are attached to fly ash. The rate at which fly ash is expelled from the incinerator depends on ash content of the MSW, design of the furnace and the combustion temperature.

Gases such as SOx, NOx, and HCl may be produced by incinerators at very low rates which can dissolve readily in water to form their corresponding strong acids. SO2 can cause direct respiratory irritation and damage materials such as stone and metal. NO2 is a major component of photochemical smog. There are trace gases that can exert a hazardous effect on living systems. Polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) thus produced are toxic to human and animal life. Other chlorinated and organic compounds arising from MSW combustion include PCBs and polycyclic aromatic hydrocarbons (PAHs) such as pyrene and chrysene which are carcinogenic.

Heavy metals released through the emission gases such as mercury, cadmium and lead are of highest health concern. Air pollution control equipment for mercury removal at combustion facilities includes activated carbon injection, sodium sulfide injection, and wet lime or limestone flue gas desulfurization. The noise from the various units of the incinerator is a major aesthetic concern. The extent of odour production and dispersion is related to the air temperature, pressure, humidity, wind speed and direction.

Disposal to MSW Landfills:

A modern sanitary landfill is an engineered facility used for disposing of solid wastes on land without creating nuisance or posing a hazard to public health or safety. The site for landfill is selected such that it should be away from airports, floodplains, fault area, seismic impact zones and unstable areas. The basic design of an MSW landfill in accordance with RCRA recommendations consists of composite liner, cover and leachate collection system.

Composite Liner System: The composite liner system consists of an upper synthetic geo-membrane liner (also known as a flexible membrane liner, FML) and a lower layer of compacted soil at least 0.61 m (2 ft) thick with a hydraulic conductivity of not greater than 1x10-7 cm/s. The clay used is naturally available clay – durable, with low hydraulic conductivity. Geo-membrane liners are liable to chemical reactions, as well as loading and settlement stresses.

Types of liners:

♣ High density poly-ethylene (HDPE)

♣ Linear low-density polyethylene (LLDPE)

♣ Polyvinyl chloride (PVC)

♣ Flexible polypropylene (FPP)

♣ Chloro-sulphonated polyethylene (CSPE) The surface of the compacted soil liner must be smooth and sufficiently strong to provide continuous support to the geo-membrane liner. At the time of installation, the geo-membrane liners are rolled out or spread out over the soil liner with each sheet overlapping the adjacent sheets and seamed together to create the effect of a single impermeable layer. [Thickness: 0.75mm to 3 mm (1.5mm for HDPE liner)]

Landfill Cover System: Daily cover is applied to the landfill with soil or any alternative material to control disease vectors, fires, odor, blowing litter, and scavenging by animals. Biological pest control methods may be a viable alternative to chemical control at landfills.

MEDICAL WASTE INCINERATION PROCESS

Properly disposing of certain kinds of waste must involve medical waste incinerators. Their use is not subjective or optional. There are federal and state guidelines that dictate exactly what type of waste needs to be incinerated and how exactly you (as the generator) need to go about storing, transporting, and disposing of that waste. If you're unaware of these laws—or simply misunderstand their rules—you are still liable to fines and other related penalties, so it's of the utmost importance that you know everything you can associated with the medical waste incineration process.

What Is a Medical Waste Incinerator?

In the world of generated medical waste, two of the most common disposal methods are incineration and autoclaving.

Whereas a medical waste autoclave runs at about 300 degrees (Fahrenheit) and sterilizes items through heated steam, an incinerator runs at 1,800 degrees.

When waste material emerges from an incinerator, all that is left is a bit of residue—also sometimes referred to as "ash" or "dust." In medical waste autoclaves, however, the items are still generally intact after the sterilization process.

What Kind of Waste Needs to Be in a Medical Waste Incinerator?

Not every type of generated waste requires incineration. However, if you're producing (or think you might produce) the following types of waste, incineration should be part of your waste disposal strategy:

- Trace chemotherapy waste.
- Pathological waste, including body parts and other biological tissues.
- Some types of hazardous waste.

Red bag medical waste (bloody or otherwise contaminated materials, such as gauze, bandages, gowns, sharps, and so on) do not require incineration. Rather, these go through the autoclave process.

Note, trace chemotherapy and pathological waste streams are technically “regulated medical waste.” However, they are not disposed of in the same manner as red bag waste.

What Happens to the Medical Waste Next?

Incineration is a critical step in the waste disposal process, but it’s not the last one. After the incineration process, the resultant dust or ash must be shipped to a Subtitle D landfill, which is intended for non-hazardous waste.

After the incineration process, a certificate of destruction can be obtained. This document can serve as a kind of insurance policy if you are ever audited or need to otherwise prove that a particular waste stream was properly disposed of.

Medical Waste Incinerators.

Medical waste incineration involves the burning of wastes produced by hospitals, veterinary facilities, and medical research facilities. These wastes include both infectious ("red bag") medical wastes as well as non-infectious, general housekeeping wastes. The emission factors presented here represent emissions when both types of these wastes are combusted rather than just infectious wastes.

Three main types of incinerators are used: controlled air, excess air, and rotary kiln. Of the incinerators identified in this study, the majority (>95 percent) are controlled air units. A small percentage (<2 percent) are excess air. Less than 1 percent were identified as rotary kiln. The rotary kiln units tend to be larger, and typically are equipped with air pollution control devices. Approximately 2 percent of the total population identified in this study were found to be equipped with air pollution control devices.

Types of incineration described in this section include:

- Controlled air,
- Excess air, and
- Rotary kiln.

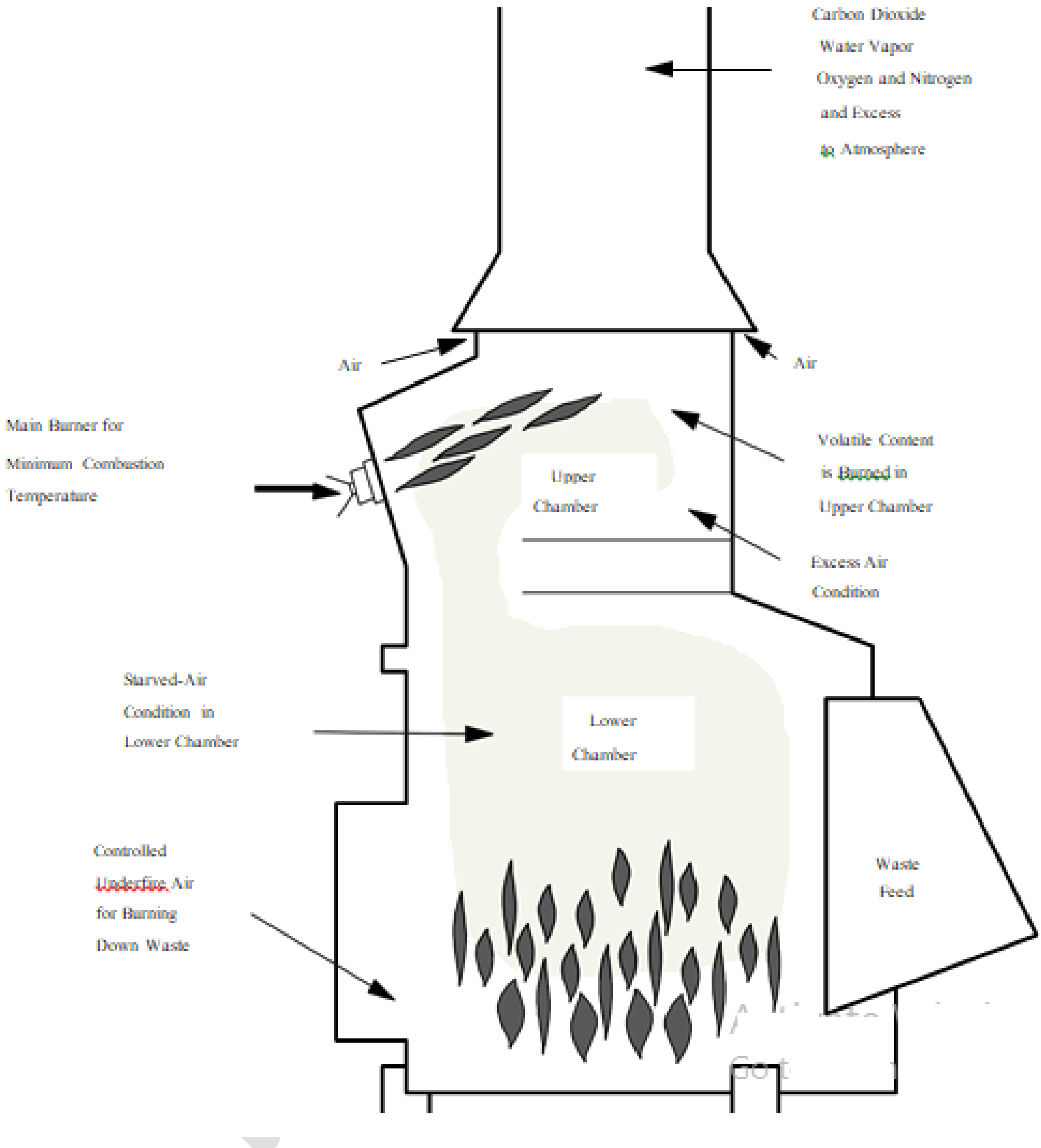
Controlled-Air Incinerators -

Controlled-air incineration is the most widely used medical waste incinerator (MWI) technology, and now dominates the market for new systems at hospitals and similar medical facilities. This technology is also known as starved-air incineration, two-stage incineration, or modular combustion.

Combustion of waste in controlled air incinerators occurs in two stages. In the first stage, waste is fed into the primary, or lower, combustion chamber, which is operated with less than the stoichiometric amount of air required for combustion. Combustion air enters the primary chamber from beneath the incinerator hearth (below the burning bed of waste). This air is called primary or underfire air. In the primary (starved-air) chamber, the low air-to-fuel ratio dries and facilitates volatilization of the waste, and most of the residual carbon in the ash burns. At these conditions, combustion gas temperatures are relatively low (760 to 980°C [1,400 to 1,800°F]).

In the second stage, excess air is added to the volatile gases formed in the primary chamber to complete combustion. Secondary chamber temperatures are higher than primary chamber temperatures-- typically 980 to 1,095°C (1,800 to 2,000°F). Depending on the heating value and moisture content of the waste, additional heat may be needed. This can be provided by auxiliary burners located at the entrance to the secondary (upper) chamber to maintain desired temperatures.

Waste feed capacities for controlled air incinerators range from about 0.6 to 50 kg/min (75 to 6,500 lb/hr) (at an assumed fuel heating value of 19,700 kJ/kg [8,500 Btu/lb]). Waste feed and ash removal can be manual or automatic, depending on the unit size and options purchased. Throughput capacities for lower heating value wastes may be higher, since feed capacities are limited by primary.



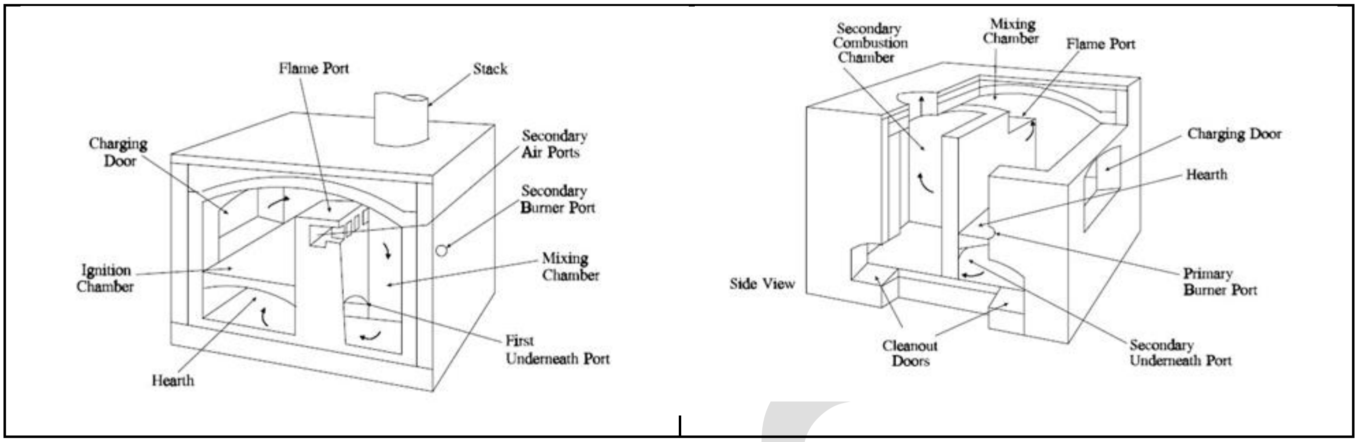
Excess Air Incinerators -

Excess air incinerators are typically small modular units. They are also referred to as batch incinerators, multiple chamber incinerators, or "retort" incinerators. Excess air incinerators are typically a compact cube with a series of internal chambers and baffles. Although they can be operated continuously, they are usually operated in a batch mode.

Figure presents a schematic for an excess air unit. Typically, waste is manually fed into the combustion chamber. The charging door is then closed, and an afterburner is ignited to bring the secondary chamber to a target temperature (typically 870 to 980°C [1600 to 1800°F]). When the target temperature is reached, the primary chamber burner ignites. The waste is dried, ignited, and combusted by heat provided by the primary chamber burner, as well as by radiant heat from the chamber walls.

Moisture and volatile components in the waste are vaporized, and pass (along with combustion gases) out of the primary chamber and through a flame port which connects the primary chamber to the secondary or mixing chamber. Secondary air is added through the flame port and is mixed with the volatile components in the secondary chamber. Burners are also installed in the secondary chamber to maintain adequate temperatures for combustion of volatile gases. Gases exiting the secondary chamber are directed to the incinerator stack or to an air pollution control device. When the waste is consumed, the primary burner shuts off. Typically, the afterburner shuts off after a set time. Once the chamber cools, ash is manually removed from the primary chamber floor and a new charge of waste can be added.

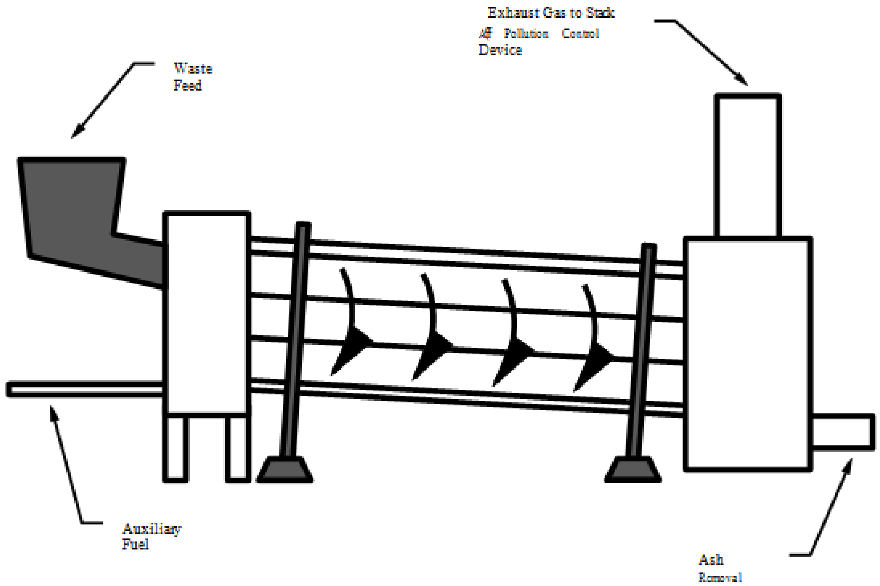
Incinerators designed to burn general hospital waste operate at excess air levels of up to 300 percent. If only pathological wastes are combusted, excess air levels near 100 percent are more common. The lower excess air helps maintain higher chamber temperature when burning high-moisture waste. Waste feed capacities for excess air incinerators are usually 3.8 kg/min (500 lb/hr) or less.



Rotary Kiln Incinerators -

Rotary kiln incinerators, like the other types, are designed with a primary chamber, where waste is heated and volatilized, and a secondary chamber, where combustion of the volatile fraction is completed. The primary chamber consists of a slightly inclined, rotating kiln in which waste materials migrate from the feed end to the ash discharge end. The waste throughput rate is controlled by adjusting the rate of kiln rotation and the angle of inclination. Combustion air enters the primary chamber through a port. An auxiliary burner is generally used to start combustion and maintain desired combustion temperatures. Both the primary and secondary chambers are usually lined with acid-resistant refractory brick, as shown in the schematic drawing, Figure.

Volatiles and combustion gases pass from the primary chamber to the secondary chamber. The secondary chamber operates at excess air. Combustion of the volatiles is completed in the secondary chamber. Due to the turbulent motion of the waste in the primary chamber, solids burnout rates and particulate entrainment in the flue gas are higher for rotary kiln incinerators than for other incinerator designs. As a result, rotary kiln incinerators generally have add-on gas cleaning devices.


Exhaust Gas to Stack
Pollution Control
Device
Waste
Feed
Auxiliary
Fuel
Ash
Removal

MODULE VI

TECHNOLOGY MANAGEMENT

INTRODUCTION

Technology is a Greek word derived from the synthesis of two words: *techne* (meaning art) and *logos* (meaning logic or science). So loosely interpreted, technology means the art of logic or the art of scientific discipline. Formally, it has been defined by Everett M. Rogers as "a design for instrumental action that reduces the uncertainty in the cause-effect relationships involved in achieving a desired outcome". That is, technology encompasses both tangible products, such as the computer, and knowledge about processes and methods, such as the technology of mass production introduced by Henry Ford and others.

Another definition was put forth by J. Paap, as quoted by Michael Bigwood in *Research-Technology Management*. Paap defined technology as "the use of science-based knowledge to meet a need." Bigwood suggests this definition "perfectly describes the concept of technology as a bridge between science and new products." Technology draws heavily on scientific advances and the understanding gained through research and development. It then leverages this information to improve both the performance and overall usefulness of products, systems, and services.

In the context of a business, technology has a wide range of potential effects on management:

- Reduced costs of operations. For example, Dell Computer Corporation used technology to lower manufacturing and administrative costs, enabling the company to sell computers cheaper than most other vendors.
- New product and new market creation. For example, Sony Corporation pioneered the technology of miniaturization to create a whole new class of portable consumer electronics (such as radios, cassette tape recorders, and CD players).
- Adaptation to changes in scale and format. In the early part of the twenty-first century, companies addressed how small devices such as cell phones, personal digital assistants (PDAs), and MP3 players could practically become, as well as how each product could

support various features and functions. For example, cell phones began to support email, web browsing, text messaging, and even picture taking as well as phone calls.

- Improved customer service. The sophisticated package-tracking system developed by Federal Express enables that company to locate a shipment while in transit and report its status to the customer. With the development of the World Wide Web, customers can find the location of their shipments without even talking to a Federal Express employee.
- Reorganized administrative operations. For example, the banking industry has reduced the cost of serving its customers by using technologies such as automated teller machines, toll-free call centers, and the Web. As of early 2005, the cost of a bank transaction conducted by a human teller was approximately $2, compared to $1 for a telephone banking transaction, $.50-1.00 for an ATM transaction, and about ten cents for banking over the Internet. Automated Clearing House (ACH) or "checkless" check processing costs were $.25-.50 per transaction. This reduction in cost could be attributed primarily to reduction the amount of labor involved, which had a profound effect on employment and labor-management relations in banking.

Professor Michael Porter of Harvard Business School is one of many business analysts who believe that technology is one of the most significant forces affecting business competition. In his book *Competitive Advantage* (1985), Porter noted that technology has the potential to change the structure of existing industries and to create new industries. It is also a great equalizer, undermining the competitive advantages of market leaders and enabling new companies to take leadership away from existing firms. In a Grant Thorton LLP survey conducted during late 2004, 47 of 100 mid-size manufacturing businesses agreed that innovation had become increasingly import to the industry. As M.F. Wolff reported, corporate strategists were encouraging this by bringing product designers along on customer visits, offering rewards and recognition programs to employees with innovative ideas, including innovation as a priority in business strategies, setting revenue goals attributable to innovation, and looking for "willingness and ability to innovate" when making hiring decisions.

TECHNOLOGY MANAGEMENT

Since technology is such a vital force, the field of technology management has emerged to address the particular ways in which companies should approach the use of technology in business strategies and operations. Technology is inherently difficult to manage because it is constantly changing, often in ways that cannot be predicted. Technology management is the set of policies and practices that leverage technologies to build, maintain, and enhance the competitive advantage of the firm on the basis of proprietary knowledge and know-how.

The U.S. National Research Council in Washington, D.C., defined management of technology (MOT) as linking "engineering, science, and management disciplines to plan, develop, and implement technological capabilities to shape and accomplish the strategic and operational objectives of an organization" (National Research Council, 1987). While technology management techniques are themselves important to firm competitiveness, they are most effective when they complement the overall strategic posture adopted by the firm. The strategic management of technology tries to create competitive by incorporating technological opportunities into the corporate strategy.

Technology management needs to be separated from research and development (R&D) management. R&D management refers to the process by which a company runs its research laboratories and other operations for the creation of new technologies. Technology management focuses on the intersection of technology and business, encompassing not only technology creation but also its application, dissemination, and impact. Michael Bigwood suggests that New Technology Exploitation (NTE) lies somewhere between R&D and New Product Development, with characteristics of the cyclical learning process of scientific discovery and the more defined and linear process of product development.

Given these trends, a new profession, known as the technology manager, emerged. Defined as a generalist with many technology-based specializations and who possessed new managerial skills, techniques, and ways of thinking, technology managers knew company strategy and how technology could be used most effectively to support firm goals and objectives.

Educational programs supporting this career grew as well. Formal Technology Management programs became available in the 1980s and these were largely affiliated with engineering or business schools. Coursework was limited, and the field was just finding its own unique focus. During the 1990s, the increasing integration of technology into overall business function and strategy helped to align technology management more closely with business programs. Most graduate programs in the 2000s were offered through business schools, either as separate MBA tracks or as MBA concentrations. Coursework in these programs shifted emphasis from technology to management, centering around innovation management and technology strategy, while touching on other areas such as operations, new product development, project management, and organizational behavior, among others. There was still little specialization in any particular industry.

During the early 2000s, another shift took place. Global distribution, outsourcing, and large-scale collaboration impacted the nature of technology management (TM) and preparatory educational programs. At least two MBA programs were shifting their technology management focus to "innovation and leadership," with particular emphasis on real-world problem solving in partnership with large corporations.

TECHNOLOGY AND INNOVATION

Technological change is a combination of two activities invention and innovation. Invention is the development of a new idea that has useful applications. Innovation is a more complex term, referring to how an invention is brought into commercial usage. The distinction between the two is very important. As an example, Henry Ford did not invent the automobile; companies in Europe such as Daimler were producing cars well before Ford founded his company. Henry Ford instead focused on the innovation of automobiles, creating a method (mass production) by which cars could be manufactured and distributed cheaply to a large number of customers.

The practice of technology management and the development of technology strategy require an understanding of the different forms of innovation and the features of each form.

- Incremental innovations exploit the potential of established designs, and often reinforce the dominance of established firms. They improve the existing functional capabilities of a technology by means of small-scale improvements in the technology's value, adding attributes such as performance, safety, quality, and cost.

- Generational or next-generation technology innovations are incremental innovations that lead to the creation of a new but not radically different system.
- Radical innovations introduce new concepts that depart significantly from past practices and help create products or processes based on a different set of engineering or scientific principles and often open up entirely new markets and potential applications. They provide new functional capabilities unavailable in previous versions of the product or service. More specifically related to business, radical innovation has been defined as "the commercialization of new products and technologies that have strong impact on the market, in terms of offering wholly new benefits, and the firm, in terms of its ability to create new businesses." (O'Connor and Ayers)
- Architectural innovations serve to extend the radical-incremental classification of innovation and introduce the notion of changes in the way in which the components of a product or system are linked together.

There are two important steps required to properly manage corporate innovation. First is to correctly identify a project as a new product vs. a technological innovation, so a proper development process can be used (the first may be a more traditional stage-gate process; the second should be more cyclical and iterative). Second, managers need to identify what category an innovation falls under, since each type of innovation has its own challenges. In the aircraft industry, for example, an improvement in the construction of a wing is an incremental innovation. Such a new technology can be introduced relatively easily and integrated with existing products. An example of a generational innovation is the introduction of the Boeing 777, a new class of aircraft different from previous models. While similar in appearance to the 767 and its predecessor, the 777 introduced a whole new set of technologies and capabilities, requiring tremendous investment by Boeing and its business partners. A radical innovation in aircraft was the introduction of the jet engine, which completely changed the performance of aircraft compared to propeller-driven airplanes. Finally, the concept of a flying machine as envisioned by the Wright Brothers exemplifies an architectural innovation. Prior to the Wright brothers, the concept of mechanical flight had been invented and discussed. The Wright brothers actually developed and demonstrated a design that made human flight a reality.

INNOVATION MANAGEMENT

Invention is an activity often identified with a single engineer or scientist working alone in a laboratory until he or she happens upon an idea that will change the world, like the light bulb. In reality, industrial invention, at least since the time of Edison, has involved many people working together in a collaborative setting to create new technology. Innovation requires an even broader set of people, including manufacturing engineers, marketing and sales managers, investors and financial managers, and business strategists. The methods for organizing this set of people to bring a new idea from the laboratory to the marketplace form the basis of the discipline of innovation management.

Innovation traditionally has been viewed as a linear process, which involves several stages in sequence: research, development, manufacturing, marketing, and ultimately, reaching the customer.

In each step, a group of employees take the idea as it is passed to them from the previous stage, modify it to accomplish a specific function, and pass it on to the next stage. Each team involved in the process has a clear function. Researchers are responsible for creating a working demonstration of the technology, developers and engineers turn it into something that can be produced, manufacturing engineers actually turn out the product, and marketers sell it to customers.

This linear model of innovation has proven to be a misconception of the process, however. For example, problems during the manufacturing process may require researchers to go back and change the technology to facilitate production. The technology may reach the marketing stage, only to turn out to be something no one wants to buy. Technology cannot be handed off between stages like a baton in a relay race. In any case, managing innovation in a sequential process would take a very long time, especially if each stage needs to perfect the technology before it can move on to the next stage. Some models simply add on to the linear stage-gate development approach, adding R&D discovery or planning phases to the front end of the process.

An alternative to the linear model of innovation was offered by the expanded, *chain-*

linked model of innovation. This model captures the interactions between the different stages of innovation in a more complete fashion. Some of the important aspects of innovation highlighted by this model are:

- Technologies can move both forwards and backwards in the process, for example going back to the lab if further development is needed.
- Downstream stages (such as marketing) can be consulted for input at earlier stages (such as design and test).
- Scientific research and engineering knowledge contributes to every stage in the innovation process.
- Most firms create technology platforms, which are generic architectures that become the basis for a variety of technology-based products and services.
- The knowledge and skills needed for innovation are developed by communities of practitioners, not by individuals, and many of those communities exist outside of a particular firm (for example, in universities).
- Users of technology can be an important source of ideas for improvements or even new innovations with substantial market potential.

While the chain-linked model of innovation is more difficult to comprehend and analyze than the linear model, it is ultimately more rewarding as it tracks more closely to the way that innovations actually progress on their way from the laboratory to the marketplace.

Another innovation process suggested was new technology exploitation (NTE), as suggested by Bigwood, which resides somewhere between new product development and "pure science." He defined NTE as "the testing of novel technical approaches specifically aimed at achieving a pre-defined result (target performance, cost reduction, etc)." It is an iterative process, allowing for the more cyclical learning process of scientific discovery, but clearly working toward tangible goals and benefits.

Another technology management process, Strategic Technology Roadmapping (TRM) was discussed by Rachel Wells et al in *Research Technology Management.* Technology road mapping is both a process and a communication. TRM aims to "integrate technology issues considerations with the strategic business context, to identify those technologies that have the greatest potential to meet business goals, and to accelerate the transfer of technology into products." TRM makes use of visual aids to show links between R&D programs, capability targets, and requirements. It also seeks to help coordinate technology plans at a strategic level, and to help senior managers make better technology investment decisions. It also helps to manage conflicts between technology "push" and market "pull," which are discussed in more detail below.

INTERNAL FORCES AFFECTING INNOVATION

While users and other external organizations are important sources of ideas for innovations, the internal organization of a company has the greatest impact on its capability for creating innovation. The ideal work environment for innovation does not exist. Instead, innovation is facilitated through the tension and balance between various conflicting but necessary forces:

- Creativity and discipline. Creative employees are needed who challenge existing assumptions and develop new and radical approaches to solving key problems. That creativity must be tempered by the discipline to capture the ideas generated by creative employees and by systematically determining which ideas can be turned into innovations, and how.
- Individuality and teamwork. Creativity is considered an individual trait, with some people being more naturally creative than others. But innovation is clearly a team effort, often involving hundreds or thousands of people. While companies should allow employees to express their individuality as a way to facilitate creative thought, that freedom must be placed in the context of the firm as a collaborative environment, where even the most brilliant individual has to work well with others for the company to succeed.
- Exploration and focus. New ideas can come from a wide variety of sources, and it is hard to predict which paths of investigation will lead to the next breakthrough technology.

Still, no firm has the resources to conduct research in every conceivable field at all times. The freedom to explore new domains of knowledge needs to be balanced by corporate decisions on what areas of investigation have the greatest promise of paying off, and focusing research in those areas.

- Long-term and short-term. Radical innovations often take years to progress from concept to tangible product. For example, the digital computer invented in the 1950s had its roots in research conducted in the mid-1800s on logic and mathematics. Unfortunately, most firms cannot spend money on research that will only begin generating revenues in ten or twenty years. Most innovative activity in firms by necessity is focused on short-term improvements and technologies. Still, firms should not lose sight of long-term innovations, as those are the technologies that can undermine existing market dominance.

One enduring debate in technology and innovation management is whether small firms are inherently more innovative than large ones. The answer appears to be different at different times. For example, the small firm Apple Computer appeared to turn out many more innovations in the 1980s than its large rival, IBM, but in the 1990s, IBM used its huge resources to regain technological dominance in computers while Apple floundered. During the 2000s, Apple came back strongly with innovative designs and technology, such as the iPod, and made big waves in the consumer arena. Also during 2004, IBM elected to sell its personal computing division to focus on information technology and software development. IBM appeared to be shedding some weight to focus on innovation and development in core business areas.

It may be more accurate to say that small firms are better organized to handle specific types of innovation compared to large firms. Small firms have very streamlined organizational structures that have few layers of management, and managers are multi-functional; i.e. they may handle business development as well as technical work, or they may be project leaders and handle company-wide finances. This cross-disciplinary approach favors flexibility and efficiency, which in turn is more conducive to radical innovation. The small firm model of organization is quite different from large established firms in which personnel in general have more narrow tasks and bureaucratic processes tend to suppress creativity and individual initiative.

Large companies are geared for production and distribution, which are large-scale undertakings that do not accommodate rapid change. Hence, the organizational structure of a large firm is quite matrix oriented engineering disciplines are assigned to projects, and a central laboratory supports research and development. Innovation is organized in a more linear fashion, and internal organization favors discipline and focus. This type of organization is better suited to incremental innovation, since it can identify problems and focus tremendous resources on solving them.

There are several ways in which small and large firms can overcome natural tendencies to gain proficiency in all types of innovation. Lockheed Martin, a large aerospace firm, was the originator of the Skunk Works, a lean, aggressive organization focused on R&D and rapid development of cutting-edge technologies. The group is kept completely isolated from the larger corporate organization, so that the engineers are unencumbered with overhead issues that are handled by other resources within the company at large. From the cultural point of view, aside from the infrastructure a large company has to handle regulatory matters as well as financial support. A small firm and a Skunk Works of a large firm can be very similar.

A small firm, in turn, can partner with a larger firm to gain access to the resources and infrastructure needed to address incremental as well as radical innovation. Carayannis et al. (1997) found that small firms tended to form technology-based strategic alliances as a source of financing. The funds gained through the alliance with a larger firm are then devoted to acquiring and developing tangible strategic assets such as proprietary technology, general working capital, and skills and know-how possessed by key managerial personnel. The large firm in the alliance receives technology-related intellectual property rights (IPRs) and marketing rights more often than equity, manufacturing rights, and so forth, in exchange for their capital infusion. An alliance with a large firm can create a powerful combination that benefits both the small company and its established partner.

Table 1
Technology vs. Market Push and Pull

The Technology Perspective

	Market Pull	Market Push
Technology Pull	*Market Satisfying*	*Technology Satisfying*
Technology Push	*Technology Satisfying*	*Market Seeding*

Technology vs. Market Push and Pull

During the early 2000s, companies were still seeking ways to build radical innovation competencies into their own organization. O'Connor and Ayers reported on a three-year study of twelve large firms (such as GE, Corning, IBM, and Shell Chemicals, among others) who worked to develop this competency, and identified three key competencies that were critical to success:

- Discovery—creation, recognition, elaboration, and articulation of opportunities
- Incubation—experimentation, technical, as well as for market learning, market creation, and matching the innovation with company strategy
- Acceleration—exploiting the technology, investing to build new business and infrastructure, responding to market opportunities

Finally, O'Connor and Ayers concluded that no one model works for all companies. Of the twelve companies studies, four had very distinct but different approaches, each influenced by that company's corporate culture. But nearly all participants in the study acknowledged a need for cultural change within the organization before radical innovation could take place.

EXTERNAL FORCES AFFECTING INNOVATION

Various forces outside the direct control of the firm can also affect the innovation process. One set of forces relates to the tension between the demands of the market and the capabilities of the technology under development.

A conventional way of analyzing technology development is to contrast the influence of *technology push* with that of *market pull*. The primary difference between a push or pull scenario is between solving a problem and accommodating a solution. Technology push is the process of solving a problem by providing a technical answer to a market need (which can be either anticipated or existing). Market pull involves solving a problem to provide a market answer to a technical need, or accommodating a technical solution by finding market uses. The dynamic balancing act between technology push and market pull drives the speed and acceleration of technological change, and in the process creates significant windows of market opportunity as well as competitive threats to the established technologies.

The terms push and pull can be expanded to encompass either a technology or market point of view:

- Technology push has been historically defined by an innovation-cycle-driven culture focused on marketing/technology management analysis. In this context, a firm's R&D division brings an idea from the invention stage to its fruition in commercial markets.
- The not-so-traditional technology pull is best described as the reaction to demand in the market. The desire for more efficient technologies by customers creates incremental improvements in these technologies that may eventually lead to a critical mass of innovations and possibly to radical improvements.
- On the other hand, market pull has been historically defined by marketing. The marketplace dictates the products that are to be supplied by a firm. In order to meet demand, a firm must constantly strive to increase performance and customer satisfaction.
- Market push is a term that addresses the creation of markets through marketing-driven efforts that, along with technology pull, can lead to the creation of technological standards that define and enable the emergence of new markets (see Figures 1 and 2).

Table 2

Technology vs. Market Push and Pull

The Market Perspective

	Market Pull	Market Push
Technology Pull	*Reacting to Demand*	*Seeding Demand*
Technology Push	*Meeting Demand*	*Anticipating Demand*

Source: Catayannis, Elias and Samanta Roy "Davids vs. Goliaths in the Small Satellite Industry: The Role of Technological Innovation Dynamics in Firm Competitiveness." *International Journal of Technovation*, under review

Technology vs. Market Push and Pull

In Figures 1 and 2, we interpret the possible configurations combining market and technology push and pull from a technology and a market perspective. The emphasis swings from a reactive stance, through an accommodating one, to a proactive one (from reacting to demand and satisfying markets to seeding and anticipating demand). The relative strength of each of the four forces (technology push or pull and market push or pull) varies during the lifecycle of the technology.

Technologies, as they develop, often follow a pattern known as the technology S-curve. In the first phase of development, tremendous investment in the technology yields relatively little improvement in performance, since the investment is devoted to researching various aspects of the technology, many of which do not have useful results. At some point, the technology takes off when a key breakthrough is made. At this critical moment, called an inflection point, the performance of the technology improves rapidly. During this second, or growth, phase, additional investment is focused on the technological breakthrough, with rapid results. As that breakthrough technology is more fully understood and exploited, the rate of improvement begins to slow and the technology enters its third phase, maturity. Finally, the technology reaches a point where additional research yields little new knowledge and few results. At this point, the technology begins the final stage, decline, and often becomes obsolete as better technologies are developed and introduced to the market.

Technology and innovation management constitute a discipline of management that continues to gain importance, impact, and attention. As technology is a pervasive force in business and in society, management of technology helps to ensure that the development of new technology and its applications are aimed at useful purposes, and that the benefits of new technology outweigh the disruptions and difficulties that accompany innovation. While it is possible to specialize in technology management, this discipline also constitutes a set of skills that all managers should possess in the modern technology-intensive and technology-driven world of business.

INVENTION

Invention, the act of bringing ideas or objects together in a novel way to create something that did not exist before.

incandescent lightbulb

The incandescent lightbulb—the quintessential invention, attributed to Thomas Alva Edison in 1879.

Building Models Of What Might Be

Ever since the first prehistoric stone tools, humans have lived in a world shaped by invention. Indeed, the brain appears to be a natural inventor. As part of the act of perception, humans assemble, arrange, and manipulate incoming sensory information so as to build a dynamic, constantly updated model of the outside world. The survival value of such a model lies in the fact that it functions as a template against which to match new experiences, so as to rapidly identify anything anomalous that might be life-threatening. Such a model would also make it possible to predict danger. The predictive act would involve the construction of hypothetical models of the way the world might be at some future point. Such models could include elements that might, for whatever reason, be assembled into novel sub models (inventive ideas).

One of the earliest and most literal examples of this model-building paradigm in action was the ancient Mesopotamian invention of writing. As early as 8000 BCE tiny geometric clay models, used to represent sheep and grain, were kept in clay envelopes, to be used as inventory tallies or else to represent goods during barter. Over time, the tokens were pressed onto the exterior of the wet envelope, which at some point was flattened into a tablet. By about 3100 BCE the impressions had become abstract designs marked on the tablet with a cut reed stalk. These pictograms, known today as cuneiform, were the first writing. And they changed the world.

Inventions almost always cause change. Paleolithic stone weapons made hunting possible and thereby triggered the emergence of permanent top-down command structures. The printing press, introduced by Johannes Gutenberg in the 15th century, once and for all curtailed the traditional authority of elders. The typewriter, brought onto the market by Christopher Latham Sholes in the 1870s, was instrumental in freeing women from housework and changing their social status for good (and also increasing the divorce rate).

What Inventors Are

Inventors are often extremely observant. In the 1940s Swiss engineer George de Mestral saw tiny hooks on the burrs clinging to his hunting jacket and invented the hook-and-loop fastener system known as Velcro.

Invention can be serendipitous. In the late 1800s a German medical scientist, Paul Ehrlich, spilled some new dye into a Petri dish containing bacilli, saw that the dye selectively stained and killed some of them, and invented chemotherapy. In the mid-1800s an American businessman, Charles Goodyear, dropped a rubber mixture containing sulfur on his hot stove and invented vulcanization.

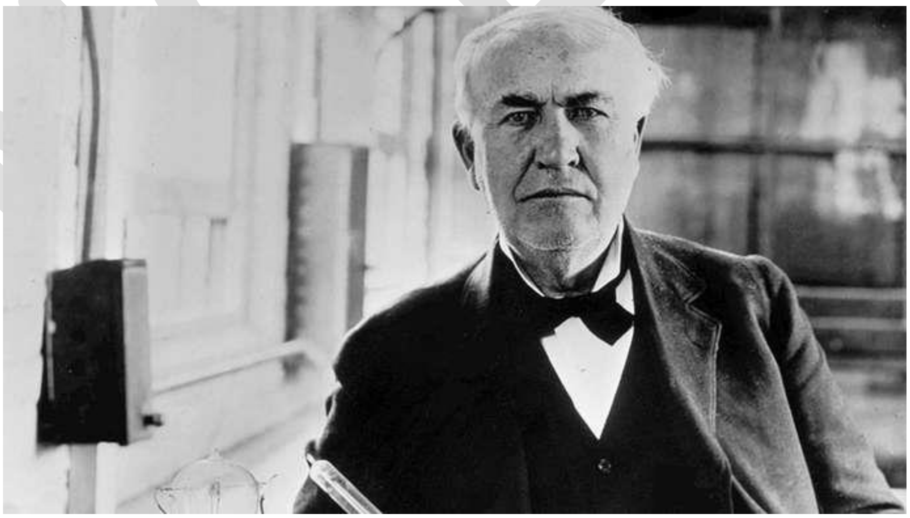
Inventors do it for money. Austrian chemist Auer von Welsbach, in developing the gas mantle in the 1880s, provided 30 extra years of profitability to the shareholders of gaslight companies (which at the time were threatened by the new electric light).

Inventions are often unintended. In the early 1890s Edward Acheson, an American entrepreneur in the field of electric lighting, was seeking to invent artificial diamonds when an electrified mix of coke and clay produced the ultrahard abrasive Carborundum. In an attempt to develop artificial quinine in the mid-1800s, British chemist William Perkin's investigation of coal tar instead created the first artificial dye, tyrian purple—which later fell into Ehrlich's Petri dish.

Inventors solve puzzles. In the course of investigating why suction pumps would lift water only about 9 metres (30 feet), Evangelista Torricelli identified air pressure and invented the barometer.

Evangelista Torricelli

Inventors are dogged. The American inventor Thomas Edison, who tested thousands of materials before he chose bamboo to make the carbon filament for his incandescent lightbulb, described his work as "one percent inspiration and 99 percent perspiration." At his laboratory in Menlo Park, New Jersey, Edison's approach was to identify a potential gap in the market and fill it with an invention. His workers were told, "There's a way to do it better. Find it."



Thomas Edison

The Quickening Pace Of Invention

Above all, invention appears primarily to involve a “1 + 1 = 3” process similar to the brain’s model-building activity, in which concepts or techniques are brought together for the first time and the outcome is more than the sum of the parts (e.g., spray + gasoline = carburetor).

carburetor

The more often ideas come together, the more frequently invention occurs. The rate of invention increased sharply, each time, when the exchange of ideas became easier after the invention of the printing press, telecommunications, the computer, and above all the Internet. Today new fields such as data mining and nanotechnology offer would-be inventors (or semi-intelligent software programs) massive amounts of “1 + 1 = 3” opportunities. As a result, the rate of innovation seems poised to increase dramatically in the coming decades.

It is going to become harder than ever to keep up with the secondary results of invention as the general public gains access to information and technology denied them for millennia and as billions of brains, each with its own natural inventive capabilities, innovate faster than social institutions can adapt. In some cases, as occurred during the global financial crisis of 2007–08, institutions will face severe challenges from the introduction of technologies for which their old-fashioned infrastructures will be ill-prepared. It may be that the only safe way to deal with the potentially disruptive effects of an avalanche of invention, so as to develop the new social processes required to manage a permanent state of change, will be to do what the brain does: invent a comprehensive virtual world in which one can safely test innovative ideas before applying them.

GREAT INVENTION CHANGES THE WORLDS TECHNOLOGY

1. FIRE - it can be argued that fire was discovered rather than invented. Certainly, early humans observed incidents of fire, but it wasn't until they figured out how to control it and produce it themselves that humans could really make use of everything this new tool had to offer. The earliest use of fire goes back as far as two million years ago, while a widespread way to utilize this technology has been dated to about 125,000 years ago. Fire gave us warmth, protection, and led to a host of other key inventions and skills like **cooking**. The ability to cook helped us get the nutrients to support our expanding brains, giving us an indisputable advantage over other primates.

2. WHEEL - the wheel was invented by Mesopotamians around 3500 B.C., to be used in the creation of pottery. About 300 years after that, the wheel was put on a chariot and the rest is history. Wheels are ubiquitous in our everyday life, facilitating our transportation and commerce.

3. NAIL - The earliest known use of this very simple but super-useful metal fastener dates back to Ancient Egypt, about 3400 B.C. If you are more partial to **screws**, they've been around since Ancient Greeks (1st or 2nd century B.C.).

4. OPTICAL LENSES - from glasses to microscopes and telescopes, optical lenses have greatly expanded the possibilities of our vision. They have a long history, first developed by ancient Egyptians and Mesopotamians, with key theories of light and vision contributed by Ancient Greeks. Optical lenses were also instrumental components in the creation of media technologies involved in photography, film and television.

5. COMPASS - this navigational device has been a major force in human exploration. The earliest compasses were made of lodestone in China between 300 and 200 B.C.

6. PAPER - invented about 100 BC in China, paper has been indispensible in allowing us to write down and share our ideas.

7. GUNPOWDER - this chemical explosive, invented in China in the 9th century, has been a major factor in military technology (and, by extension, in wars that changed the course of human history).

8. PRINTING PRESS - invented in 1439 by the German Johannes Gutenberg, this device in many ways laid the foundation for our modern age. It allowed ink to be transferred from the movable type to paper in a mechanized way. This revolutionized the spread of knowledge and religion as previously books were generally hand-written (often by monks).

9. ELECTRICITY - utilization of electricity is a process to which a number of bright minds have contributed over thousands of years, going all the way back to Ancient Egypt and Ancient Greece, when Thales of Miletus conducted the earliest research into the phenomenon. The 18th-century American Renaissance man Benjamin Franklin is generally credited with significantly furthering our understanding of electricity, if not its discovery. It's hard to overestimate how important electricity has become to humanity as it runs the majority of our gadgetry and shapes our way of life. The invention of the **light bulb**, although a separate contribution, attributed to Thomas Edison in 1879, is certainly a major extension of the ability to harness electricity. It has profoundly changed the way we live, work as well as the look and functioning of our cities.

10. STEAM ENGINE - invented between 1763 and 1775 by Scottish inventor James Watt (who built upon the ideas of previous steam engine attempts like the 1712 Newcomen engine), the steam engine powered trains, ships, factories and the Industrial Revolution as a whole.

11. INTERNAL COMBUSTION ENGINE - the 19th-century invention (created by Belgian engineer Etienne Lenoir in 1859 and improved by Germany's Nikolaus Otto in 1876), this engine that converts chemical energy into mechanical energy overtook the steam engine and is used in modern cars and planes. Elon Musk's electric car company Tesla, among others, is currently trying to revolutionize technology in this arena once again.

12. TELEPHONE - although he was not the only one working on this kind of tech, Scottish-born inventor Alexander Graham Bell got the first patent for an electric telephone in 1876. Certainly, this instrument has revolutionized our ability to communicate.

13. VACCINATION - while sometimes controversial, the practice of vaccination is responsible for eradicating diseases and extending the human lifespan. The first vaccine (for smallpox) was developed by Edward Jenner in 1796. A rabies vaccine was developed by the French chemist and biologist Louis Pasteur in 1885, who is credited with making vaccination the major part of medicine that is it today. Pasteur is also responsible for inventing the food safety process of **pasteurization**, that bears his name.

14. CARS - cars completely changed the way we travel, as well as the design of our cities, and thrust the concept of the assembly line into the mainstream. They were invented in their modern form in the late 19th century by a number of individuals, with special credit going to the German Karl Benz for creating what's considered the first practical motorcar in 1885.

15. AEROPLANE - invented in 1903 by the American Wright brothers, planes brought the world closer together, allowing us to travel quickly over great distances. This technology has broadened minds through enormous cultural exchanges—but it also escalated the reach of the world wars that would soon break out, and the severity of every war thereafter.

16. PENICILLIN - discovered by the Scottish scientist Alexander Fleming in 1928, this drug transformed medicine by its ability to cure infectious bacterial diseases. It began the era of antibiotics.

17. ROCKETS - while the invention of early rockets is credited to the Ancient Chinese, the modern rocket is a 20th century contribution to humanity, responsible for transforming military capabilities and allowing human space exploration.

18. NUCLEAR FISSION - this process of splitting atoms to release a tremendous amount of energy led to the creation of nuclear reactors and atomic bombs. It was the culmination of work by a number of prominent (mostly Nobel Prize-winning) 20th-century scientists, but the specific discovery of nuclear fission is generally credited to the Germans Otto Hahn and Fritz Stassmann, working with the Austrians Lise Meitner and Otto Frisch.

19. SEMICONDUCTORS - they are at the foundation of electronic devices and the modern Digital Age. Mostly made of silicon, semiconductor devices are behind the nickname of “Silicon Valley", home to today's major U.S. computing companies. The first device containing semiconductor material was demonstrated in 1947 by America's John Bardeen, Walter Brattain and William Shockley of Bell Labs.

20. PERSONAL COMPUTER - invented in the 1970s, personal computers greatly expanded human capabilities. While your smartphone is more powerful, one of the earliest PCs was introduced in 1974 by Micro Instrumentation and Telemetry Systems (MITS) via a mail-order computer kit called the *Altair*. From there, companies like Apple, Microsoft, and IBM have redefined personal computing.

21. THE INTERNET - while the worldwide network of computers (which you used to find this article) has been in development since the 1960s, when it took the shape of U.S. Defense Department's ARPANET, the Internet as we know it today is an even more modern invention. 1990s creation of the World Wide Web by England's Tim Berners-Lee is responsible for transforming our communication, commerce, entertainment, politics, you name it.

DIFFERENCE BETWEEN INVENTION AND INNOVATION

We all are aware of the fact that nothing is permanent in this world, neither products nor technology. As day by day, improvements and updating are made in technology, leading to new inventions and innovations in every sphere of life. **Invention** refers to the creation of a brand new product or device. Conversely, **innovation** is an act of making changes to the existing product or the process by introducing new ways or ideas.

At first sight, the two terms sound alike, but if you dig deeper, you will find that there is a fine line of difference between invention and innovation that lies in their connotations. While invention is all about creating or designing something, innovation is the process of turning a creative idea into reality.

Definition of Invention

The term 'invention', is defined as the act of creating, designing or discovering a device, method, process, that has not existed before. In finer terms, it is a novel scientific idea conceived through research and experimentation that turns into a tangible object. It can be a new process of producing a product or may be an improvement upon a product or a new product.

Inventions can be patented, as it provides security to the inventor, for intellectual property rights, and also identifies it as an actual invention. Further, different countries have different rules for obtaining the patent and the process is also costly. To be patented, the invention must be novel, have value and non-obvious.

Definition of Innovation

The word 'innovation' itself signifies its meaning, as the transformation of an idea into reality. In the purest sense, innovation can be described as a change that adds value to the products or services; that fulfills the needs of the customers. It is when something new and effective is introduced to the market, that fulfills the needs of the customers by delivering better products and services.

Innovation can be an introduction or development of new product, process, technology, service or improving/redesigning the existing ones that provide solutions to the current market requirements. All the process that help in the generation of the new idea and translating it into the products demanded by the customers are covered under innovation.

Key Differences Between Invention and Innovation

The significant differences between invention and innovation are classified below:

1. The occurrence of an idea for a product or process that has never been made before is called the invention. The implementation of the idea for product or process for the very first time is called innovation.
2. The invention is related to the creation of new product. On the other hand, innovation means adding value or making a change in the existing product.
3. The invention is coming up with a fresh idea and how it works in theory. As opposed to innovation, is all about practical implementation of the new idea.
4. The invention requires scientific skills. Unlike innovation, which requires a broad set of marketing, technical and strategic skills.
5. The invention occurs when a new idea strikes a scientist. Conversely, innovation arises

when a need realized for a new product or improvisation in the existing product.

6. The invention is concerned with a single product or process. As against this, innovation focuses on the combination of various products and services.
7. While the invention is limited to research and development department of the organization. Innovation is spread all over the organization.

Differences between invention and innovation

1. Meaning

Invention refers to the development of something that is entirely new, and which has never been created before. On the other hand, innovation refers to the introduction of fresh ideas and technology to an already existing product or service. In other words, innovation makes use of an invention in a unique way to make it popular among the customers.

2. Skills required

An invention is brought about by someone who possess technical skills. On the other hand, innovation requires a range of strategic, technical and marketing skills.

3. Brought about by

Invention comes about when a scientist thinks of a new idea regarding a product or service. On the other hand, innovation comes about when a need for a unique product or service, or an improvement in an existing product or service is identified

4. Involves

Invention involves a single product, service or process, while innovation is a mix of different products, services or processes.

5. Carried out by

Invention is carried out by a scientist who comes up with a new idea, while innovation is carried out by an entrepreneur who identifies the need for a different product.

INVENTION	INNOVATION
MEANING	
Coming up with an idea, or developing a new product or service, that has not been created previously	Bringing about changes or improvements in a product or service already present in the market, with the aim of adding value to it
SKILLS REQUIRED	
Technical skills	Strategic, marketing and technical skills
BROUGHT ABOUT BY	
A new idea comes in the mind of inventor	A need for a distinct product or service, or enhancements in an existing product
INVOLVES	
Single product or service	A mix of different products or services
CARRIED OUT BY	
Scientific	Entrepreneur

INTELLECTUAL PROPERTY RIGHTS (IPR)

Definition of IPR:

In the common sense intellectual property is a product of mind. It is similar to the property (consisting of movable or immovable things) like a house or a car where in the property or owner may use his property as he wishes and nobody else can use his property without his permission as per Indian laws.

Function of IPR:

World intellectual property organization (1967) one of the specialised agencies of the United Nations system provided that intellectual property shall include rights relating to the following:

(a) Literary, artistic and scientific works, performance of artists, phonograms and broadcast; innovation in all fields of human endeavor; scientific discoveries; trademarks, service marks and commercial names; industrial designs; protection against unfair competition and all other rights resulting from intellectual activity in the area of industrial, scientific, literary or artistic fields.

(b) The intellectual property is protected by and governed by appropriate national legislations. The national legislation specifically described the inventions, which are the subject matter of protection and those which are excluded from a protection, for example methods of the treatment of humans or therapy and invention whose use would be contrary to law or invention which are injurious to public health are excluded from patentability in the Indian legislation.

Forms of Protection:

The forms of protection are as follows:

(i) Patents:

A patent is a government granted and secured legal right to prevent others from making, using or selling the inventions covered by the patent. A patent is a personal property which can be licensed or sold by the person/organisation like any other property. For example Alexander Graham Bell obtained patent for his telephone. This gave him the power to prevent anyone else from making or using or selling a telephone.

It has been reported that the first patent was granted to Filippo Brunelleschi in the Republic of Florence of the Italian city states in 1421 on the discovery of special hoisting gear used on barges. An ordinance issued in a vential law in 1474 on patents. Later, in England, during 1533-1603, minister.

Lord Burghley (1520-1598) in the ministry of Elizabeth granted a series of patents with a view to inculcate and encourage inventors working in England. In India, the basics of intellectual property rights were first introduced by enacting the Act on protection of inventors in 1856 which was based on British Patent Law of 1852. Later, series of patent legislation established as shown below.

International and national agreements and treaties were founded as given below:

Year	Act/Law
1856	Act on Protection of Invention
1859	Patent monopolies of making, selling and using invention in India and authorizing others to do so for 14 years from date of filling application
1872	Patents & Design of protection
1883	Protection of Invention Act
1888	Consolidation as the Invention & Designs Act
1911	Indian patents and designs act w.e.f. August 15, 1947
1914	British Copyright Act 1911 modified for British India
1940	Legislation for protection of the Trade mark act w.e.f. June 1, 1942
1957	Adopted many principles for British Copyright Act
1959	Indian Trade & Merchandise Marks Act
1967	Patent bill introduced in Parliament
1970	Indian Patents Act
1970	Patents Act (Act 39 of 1970) introduced w.e.f. April 20, 1972
1983	Amendments to avail the benefits arising from the revision of the Berne convention and the Universal Copyright convention
1983	Amendments to discourage and prevent piracy.
1992	Amendment to increase protection time to Author's Life time + 60 years
1992	Amendment proposed for a "New Act": debates continuing
1993	Ordinance framed to amend the Patents Act, 1970 and the concept of exclusive marketing rights introduced as pipeline protection
1994	Amendment due to obligation arising from the General Agreement of Trade & Tariff (GATT), copyright protection extended to computer industry.

As far as International and Regional agreements/treatises in Intellectual Property Rights are concerned, it began from 1883 with Paris convention for the protection of Industrial Property; Berne convention for the protection of Literacy and Artistic works (1886); Madrid agreement for Repression of false or deceptive indications of source of goods (1891); Hauge agreement concerning the International Deposit of Industrial designs (1925); Nice agreement concerning the International classification of Goods and services for the purposes of the Registration of Marks (1957); Lisbon agreement for the protection of appellation of origin and their International Registration (1958); Rome convention for the protection of performers, producers of phonograms and broadcasting organizations (1961); Locarno Agreement establishing an International classification for industrial designs (1968); Patent cooperation treaty (PCT in the year 1970); Strasbourg agreement concerning the International Patent Classification and Geneva convention for the protection of producers of phonograms against unauthorized duplication of phonograms (1971); Vienna agreement establishing an international classification of the figurative elements of marks (1973); Brussels convention relating to the distribution of programme carrying signals transmitted by satellites (1974); Budapest treaty on the International Recognition of the Deposit of Microorganisms for the purposes of patent procedures (1977);

Nairobi treaty on the protection of Olympic symbol (1981); Protocol relating to the Madrid agreement concerning the International Registration of Marks (1989); Trademark law treaty and trademark related Intellectual property Rights (TRIPS) 1994; Community Trademark (1996), Documents for the diplomatic conference on certain copyrights and Neighbouring Rights (1996), WIPO Copyright Treaty WCT) and WIPO Performance and Phonograms Treaty (WPPT).

In India, the Controller General of Patents Designs and Trademarks (CGPDT) functioning under the Department of Industrial Development Control grant the patents, designs and trademarks. The Ministry of Human Resources and Development is in-charge of copyright board.

(a) Conditions for patentability:

An invention or process is patentable if it is new, involves an inventive step (i.e. it is not obvious) and is industrially applicable.

(b) Test of novelty of patents:

Patents specifications should be made before the date of filling of the application with complete information. Any other document published in India or elsewhere before the date of the filling of the applicants complete specifications. This will cover forcing specifications whether publishing in India or not and text books and periodicals published any where related to the art in question. The only limitations being that they should be published before the date of the filling of the applicants complete specifications.

The economic and competitive position of a fermentation process depends on several factors such as yields, research costs, and size of the market, profit potential, and patent or secret, process position of the fermentation process or product. Patents are granted to inventors in return for a public disclosure of their inventions.

This disclosure and the knowledge of the respective art help to advance the state of that art. The patent in terms gives the inventor the right to exclude others from making, using or selling his particular invention as disclosed in the “claims” of the patent. Obviously, in case of certain inventions secrecy is difficult to maintain, for example in the process of fermentation.

The individuals working in an industrial research laboratory or any laboratory in which fermentation process of potential economic value are under study should know about how to read a patent in order to be able to determine the points of the invention which are actually protected by the patent.

He should also understand the types of information's that are required for filling a patent application so that research can be directed towards obtaining information. As we shall see claiming too little or too much about the process or product can be disastrous. Guidance in these problems can be obtained from a qualified patent attorney.

(c) Composition of a patent:

A patent consists of three parts, the grant, specifications and claims. The grant is filled at the patent office and is not published. It is signed document and is the agreement that grant patents right to the inventor. The specifications and claims are published as a single document which is available to the public at a minimum charge from the patent office.

The specification section is narrative description of the subject matter of the invention and of how the invention is carried out; the claims section specifically defines the scope of the invention to be protected by the patent that which other may not practice. Thus, a patent stands of falls depending upon the statements included in the claims section.

Recently, Madras High Court dismissed the petition by the Swish Pharma, Novartis challenging the constitution of Section 3(d) of Indian Patents Act. The petition was rejected. The company was seeking the patent for incremental innovations done on the decades old medicines.

The Section 3(d) of the new Patent Act stipulates that incremental innovations or any of modifications must enhance the efficacy of the drug substantially to quality for fresh patenting. There is no logic for prolonging the patent period after its expiry just on account of frivolous charges. Madras High court properly interpreted it and did not allow its approval. This will stop the exploitation by minor inconsequential modifications in the original patent.

(ii) Copyrights:

Copyrights broadly include literacy works, musical works, including any accompanying works, dramatics works, including any accompanying music pantomimes and choreographic works, pictorial graphics and sculptural works.

Recently an expression called neighboring rights has been added to the concept of copyrights. The expression neighboring rights is the abbreviated form of the rights neighboring on copyright.

The following three types of rights are covered by the concept of neighboring rights:

(a) The rights of performing artists in their performance

(b) The rights of producers of phonograms in their phonograms

(c) The rights of broadcasting organizations in their radio and television broadcasts.

(iii) Trade Mark:

A trade mark is an identification symbol which is used in the course of trade to enable the public to distinguish on trader's good from the similar goods of other traders.

The public makes use of these trade works in order to choose whose goods they will have to buy. If they are satisfied with the purchase, they can simply repeat their order by using the trade mark, for example KODAK for photography goods and IBM for computers. Zodiac for readymade clothes, etc.

(iv) Design:

Design means only the features of shape, configuration, pattern or ornament applied to any article in any industrial process or means whether manual, mechanical, chemical, separate or combined, which is the finished form appeal to end or judged solely by the eye. By registration under the designs act, the features are protected as design.

Genetic information's can also be used to cure a disease, for example using the technology of gene therapy with a specific gene vector. The direct use of proteins as therapy is well established, and these products may be patented, though we should note, in general, that medical procedures have not been patented for ethical and practical reasons.

A patented product that reaches the commercial market gives the inventors some compensation for the time they spent in research for the development. In the USA, the average time required for biotechnology medicine to be approved for commercial scale of food & drug administration is 21.4 months after requests of trial based on chemical tests and it should be ten years after identifying the substance.

Once a product is patented the sales can bring about high income for the company that produces it and this includes return for the inventors. The system is self sustaining; if patents are awarded, companies will invest time in research and if not, these will be less incentive for companies to do research.

Without patents it may be easy for other companies to copy the techniques soon after introducing and take a share of the commercial market, especially because they do not need to bear the cost of the long period of research for product development.

Some system of reward is required to encourage commercial research, which is responsible for a significant number of biotechnology applications. The international recognition of intellectual properly rights (patents variety rights) is thus a basic concern.

The ethical principle of beneficence can be applied here. Does commercialization of biotechnology leads to more benefits than a bar on it? The benefits should be in terms of general, medical or agriculture developments, rather than the economic prosperity of one company or country over another.

Patenting is not permitted useful information otherwise becomes trade secrets, or if plant variety rights are not recognized seeds may not be made widely available. However, property rights are not absolutely protected in any society because of the principle of justice, and for the sake of "public interest", "social need,"; and "public-utility", societies can confiscate intellectual property.

People arguing for patenting claim that patent laws regulate inventiveness and not commercial uses of inventions. However, there was recent controversy regarding the commercial monopoly held by the company which was able to protect the first HIV/AIDS treatment, which enable to obtain large projects while it held a monopoly.

It also meant that the drug was prohibitively expensive for developing countries. Another arrangement is that if other countries support patents, our country needs to if our biotechnology company is to compete; however, the reverse arrangement that some countries do not permit similar patents, is also used to justify exclusions.

(v) Know-how:

Know-how is another important form of intellectual property generated by R&D institution that does not have the benefit of patent protection. This could be in the form of an aggregations of known procedures and accumulation of data. A secret formulation or a combination of any of these know-how is often transferred together with licensing of patent.

Patenting of Biotechnological Discoveries:

The question arises what properties must a product have in order for it to be patentable? Actually, there is some debate about whether living organisms should be patented.

Following characters are to be considered to qualify for a patent:

(a) Novel invention,

(b) Non-obvious,

(c) Usefulness.

In the case of natural products, details of four molecules or coding nucleic acid sequence may have lost its novelty and non-obviousness. Patents are granted on molecules which have medical uses if the chemical structure or the useful activity was novel when the patent was applied for methods of gene-sequencing, mapping or expression, can be invented or patented.

The process for making 'oncomouse', a mouse that contains activated oncogenes sequences that are; therefore, sensitive to mutagens or carcinogens was patented in 1998 in the USA. Protected by copy right law is creativity in the choice and arrangement of words against those who 'copy'; who take and use the form in which the original work has expressed by the author e.g. such as books, photographical works, paintings etc.

Bio-Piracy:

There has been growing discontent amongst developing countries about this bio-piracy i.e. unfair exploitation and monopolization of public domain knowledge and resources. Most of the industries of developed nation's recent losses come from counterfeit goods and pirated technology in the developing countries.

A new drug generally takes a decade or so involving several lakhs of rupees to develop. Intellectual Property Rights (IPRs) are justified to protect this enormous amount of investment. On the other hand, developed countries freely acquired most of its live material including crops from its neighbours.

Developed countries also looted medicinal plants, dyes, spices, etc. from developing countries leading to discovery and conquest of India, S. America and S.E. Asia. For example, new drug like resperine used against hypertension. Derived from an Indian Plant sarapagandha (Rauwolfia serpentina) has enormously enriched foreign drug companies.

Similarly, genes from the Pattambi rice variety in Kerala (S. India) have been used to introduce to pest resistance in paddy. Now seed companies have started exploiting this character without giving any advantage to farmers. The developed countries have never paid for the benefits obtained from the developing countries.

On the other hand, they get raw material of basic knowledge from developing countries but selling back on a very high price. Since, IPRs protect only the commercial inventions; the domestic and ongoing use of bio-resources is not prevented. Thus, grand parents or ayurvedic practitioners can continue to use of market churan or decoctions as usual. However, they are not entitled for the claim from the profits out of these items.

Industrial Property:

Industrial property includes inventions (process, products, apparatus); industrial designs (shapes & ornamentation); and Marks and Trade names to distinguish goods. Recently, the scope of industrial property has been expanded to include among others, the protection of distinctive geographical indications (in particular appellation of origin), plant varieties and the layout designs (topographies) or integrated circuits as well as the repression of unfair competition, including the protection of trade secrets.

Importance in Indian Scenario:

A US patent granted for use of turmeric powder (haldi) as a wound healing agent to the University of Mississippi, Medical Centre, US, has been revoked following objections by the Council of Scientific and Indian Research (CSIR), New Delhi.

The revocation order was passed on August 13, 1997, two years after the grant of patent in March 1995. It was a legal battle on turmeric powder which is used in India for ages now as a wound healing agent among other things, and was not a discovery of the US patentee.

Now patents have already been granted for food stuffs like idli, dosa, vada, churan, pickle, halwa and pizza topping. The Indian patents Act 1970 stresses that any patentable commodity must possess novelty. Apparently, the Chennai Patent office believes that South Indian delicacies like "medu vadai". "rava-uppuma", "badam halwa", "rice idli", "rice pongal", and even Green Peas Masala are novel process. Patent rights for these popular preparations were granted to the Dasaprakash hotel chain in 1973.

The Mumbai office of the Patents has granted one Dilip Shantaram Dahanunkar, a process patent for the preparation of tomato rasam and a custard chilli jam spread used as a pizza topping. The same person has been given a patent for an improved process for preparation of vitaminised sweet and sour lemon pickle rice and a process for manufacturing banana sauce.

The purpose of patenting common products seems to improve their marketability rather than to protect "inventions". Accordingly, inventors blindly exploit legal loopholes to patent age-old products.

According to Calcutta based patent and trademark attorney, D.P. Ahuja and company the Patents Act, 1970 states that a patent can be given for a novel article or a process even if it results in an old product.

On 30 September 1997, the European Patent Office (EPO) delivered a favourable interim judgment on the challenge of a European patent on the fungicide effects of neem oil (Patent No. 436 257 BY) owned by W.R. Grace & Co. The opposition division of the EPO issued a provisional statement on the basis of the European Patent convention (EPO) and delivered favourable interim judgment on opposition to Neem Patent, in favour of Dr. Vandana Shiva, Ms. Magda Alvoet (MP of the European parliament) and other NGOs of Neem campaign.

Recently, another controversy has arisen regarding patenting of ‘Basmati Rice’ by U.S.A. Indian Govt. filed reexamination request for the patent on Basmati rice lines and grains (US Patent no. 5666484) granted by US PTO , and Ricetech Co. from Texas has decided to withdraw the specific claims challenged by India.

There is problem on the grant of such patents linked to the indigenous knowledge of the developing world that needs to be addressed jointly by the developing and the developed world. Actually, the available data bases of different items available in patent international offices are to be considered by patent examiners while granting the patents.

They search non-patent literature database that deal with traditional knowledge, captured electronically and placed in the appropriate classification within the international patent classification systems so that it can be easily searched and retrieved in the international patent office. This would help prevent the patenting of the products that have been based on the traditional knowledge of the developing world.

The Indian Govt. has taken a step to create a Traditional Knowledge Digital Library (TKDL) on traditional medicinal plants and systems, which will also lead to a Traditional Knowledge Resource Classification (TKRC).

Such information shall fill up the gap between the knowledge contained in an old sanskrit shloka and the computer screen data of a patent examiner in Washington. This will eliminate the possibility of granting wrong patents since the Indian rights to that knowledge will be known to the examiners. Some of the countries are in process of securing patents (Table 1.3).

Table 1.3 : Patents secured abroad and country of origins.

Country of origin	Number of patents Secured
India	78
USA	1,09,146
Japan	80,905
Israel	933
Luxembourg	613
Brazil	275

Above data for the year 1995 is based on The Express Magazine, May 3, 1998.

Forthcoming Laws:

New laws to be enacted by government of India so as to bring India closer to the international patents regine.

New laws relating to intellectual property rights that the government proposes to enact, are given below:

(i) Trade Marks:

This Act will allow the registration of service marks and collective marks. The service mark will allow the entire service industry to register its logos that identify a firm while the collective mark will allow entrepreneurs from a certain region that is famous for a particular region. For example, all makers of footwear from Kolhapur will be able to register the name Kolhapuri so; anyone manufacturing chappals outside the town shall not be allowed to use its name.

(ii) Geographical Indicators:

Basmati is the suitable example which allows a country to register all products whose quality, reputation or other characteristics are essentially attributable to their geographical regions.

(iii) Industrial Designs:

India's industrial design law dates back to 1911. It badly needs to be updated.

(iv) Layout/Designs of Integrated Circuits:

India has a role to play in world's electronic market. The protection of integrated circuits is crucial to the development of the electronic industry. This is essential so that efficiency and the capability of each circuit is maintained.

(v) Trade secrets:

This is something great that India does not have trade secrets. It will allow a company to register and protect formula details or processes. A patent usually runs out in 10-20 years, but under this law a company will have no obligation to reveal its secret. Coca-Cola, for example has covered its best-kept secret of its formula under this law.

SOME FREE PATENT SEARCH WEBSITE

Some of the free patent search databases and their basic functionality are listed below:

1. Free patents online

In this website, the user can choose to conduct a country-specific search. The patent sources of the countries available in this website are: US Patents, US Patent Applications, EP documents, Abstracts of Japan, WIPO (PCT), German Patents (Beta). Even non-patent literature may be accessed with this database. (Non-patent literature refers to that documents and publications that are not patents but are cited as references for being relevant in a patent prosecution). The database also has an option of expert search or quick search. In a quick search, the user may conduct the patent search according to the various headings such as date of filing, publication date, name of assignee, name of inventor and so on.

2. Espacenet

This database allows full-text searches in English, French or German. It has three options for search; Smart search, Advanced search, and Classification search. In the advanced search, the user can conduct the search under different headings such as title, abstract, publication number and so on. The classification search allows the user to search for a specific class.

3. Patentscope (WIPO)

This database has the options of simple, advanced search, field combination, and cross lingual expansion. Simple search allows search by name, date, international classification and so on.

Field combination has the following headings under which the search may be conducted: WIPO publication number, application number and so on in combination with Booleans.

4. USPTO Patent Search

This database allows patent search to be conducted using the following resources:

USPTO Patent Full-Text and Image Database (PatFT)

USPTO Patent Application Full-Text and Image Database (AppFT)

Global Patent Search Network (GPSN)

Patent Application Information Retrieval (PAIR)

Public Search Facility

Patent and Trademark Resource Centers (PTRCs)

Patent Official Gazette

Common Citation Document (CCD)

Search International Patent Offices

Search Published Sequences

Patent Assignment Search

5. Google Patents Search

It has separate sections for patent search and prior art finder. The patent search has the option of including non-patent literature, and you can learn more about here.

6. InPASS

This Indian patent office database allows for a full-text search of all Indian patents and Patent Applications. Apart from this, InPASS also allows a person to conduct a free patent search using Wild Cards and Boolean Operators. Additionally, how to use InPASS, please refer the blog post how to conduct Indian patent search.

Key Difference between Patents, Trade Marks, Trade Secret and Copy Right

There is a difference between patents, trademarks, and copyrights. Depending on the work you are trying to protect, you may use one or more of these intellectual property tools to protect your work. Some of these tools are patents, trademarks, copyrights, and trade secrets. To understand when to use which and the difference between patents, trademarks, copyrights, and trade secrets, let's take a look at the definition of each IP tool.

Patents: Patents protect new, useful, and non-obvious inventions (ideas!). An invention can be a device, a structure, process, machinery, etc.

Trademarks: Trademarks protect source identifications, usually for brands, slogans, logos, or designs (sometimes even scents or colors). A trademark protection may extend perpetually.

Copyrights: Copyrights protect original textual works and visual or artistic expressions.

Trade Secrets: Trade secrets protect valuable secret information like ideas that must be kept confidential. Others to whom they are disclosed to must also keep them confidential. Similar to trademarks, trade secret protection may extend perpetually.

INTRODUCTION TO TECHNOLOGY TRANSFER

The laws of nature ultimately limit technological improvement in any field. For example, the number of transistors that can be placed on a silicon chip is limited by the crystal structure of silicon. Most industries are however far from these limits, and they are much more likely to come up against practical technological limits. For instance the efficiency of today's car engines can greatly be improved, when the operating temperatures can be increased. Current alloys however cannot withstand these temperatures, but there are materials such as ceramics that can operate at these temperatures. The problem, however, is that ceramics are not practical to use because of characteristics like their strength. Ongoing research is taking place in this field.' Researchers therefore strive to narrow the gap between the current technology and the limit be it practical or physical. This gap is called the technical potential of technology. Many believe that the technology with the greatest potential, will take control of the market. Researchers must realize that technological advancement is not only achieved by improving current technology, but also through the development of new technology. Often there are gaps between current and new technology, and that is what makes developing new technology so difficult. These gaps may also be just big enough for people not to see the benefits of the new technology. This blindness has effected almost every industry. Aspects that may stand in the way of adopting new technology and discarding the old may include:

- Incorrect perspective of technical limits
- Inability to measure technological progress
- Faulty interpretations of market signals
- Misinterpreted customer needs Culture
- Gap between old and new technology is too big.

Can an organization really sit and wait for market clues before they change their technology? Certainly not. An organization must realize that the clues from the market are signaled to all competitors in the market. Organizations must also be aware of the fact that the market is becoming more and more sophisticated and educated. This means that they want their needs to be satisfied in a unique way. The strategy to copy the competitor's way of satisfying needs might therefore not be enough, and such organizations will act as followers to the leaders in the industry.

The biggest impediment in the introduction of new technology into an organization is company culture. People do not like change and they would rather stick to what they are familiar with, rather than introducing something new. Another obstacle, which can also be associated with culture, is the mindset to introduce a new technology and then put a lot of effort into protecting and defending it. This might not be the best strategy. An organization is not married to the technology it employs. Organizations must see technology as an expendable tool and if the need change, so must the tool.

The question may then be asked, "what is the best strategy"? There is not one strategy that can be classified as 'best', but the following aspects should be incorporated in a strategy:

• Knowing the technology welfare of your organization

• Knowing the technology position of the competition

• Knowing what technologies are available

Since the shift to new technology can take as long as a decade, companies need an early warning system of advancing new technology. One way is to identify technological alternatives on a continuous basis. People in decision making positions should stay abreast of developments in their industry. They must therefore be aware of what is available to them, what their current technological position is and in what technological position their competitors are in.

Technology can therefore play a major role in business and is an aspect that is receiving growing attention. Acquiring the most appropriate technology can therefore place an organization in a very competitive position.

The need to initiate a technology transfer project can originate from two forces'. The first can be described as a technology push. In this case a technology has been developed and is 'searching' for an application. This is very often a spin-off from another research program, and the technology was not developed with an application in mind. In essence the technology was identified before the need.

The second situation is a demand-pull. In this situation the need is identified before the technology is developed. The technology can either be developed exclusively to satisfy the need, or an existing technology can be transferred and customized in order to satisfy the need.

It is clear that the strategies will differ between a technology push and a demand pull situation. In the first case a company will transfer technology, because they feel they can usefully apply the technology. The technology can be applied either in a new application or in a current application, thereby updating older technology. Senior management, however, must have the vision and insight to employ such a strategy, because they must make the connection between the technology and the application thereof.

In the second case a solution to a problem is sought and that will be the motivation for transferring the appropriate technology. For the purpose of this investigation the focus will be on a demand-pull situation.

Technology Transfer Process

The transfer process of technology can be coupled to the general innovation process. Technology transfer is, however, not present in every step of the innovation process and we will only look at those steps where transfer is involved. The steps can be defined as follow:

- Identifying appropriate technology
- Evaluate the technology
- Secure the technology
- Protect the technology
- Produce prototype
- Obtain technology awareness training
- Product specific training

In order to apply these steps in a more general environment Cooke and May defined the major steps of the technology transfer process as being:

- Searching
- Finding
- Evaluating
- Acquiring
- Customizing
- Operating

It is important to note that in the transfer process, extensive use is made of project management principles. A transfer project is a unique endeavor until the technology is operational in the company. Companies should therefore ensure that they are familiar with project management principles in order to ensure a smooth transfer process.

Recognizing a need or opportunity

As mentioned before, the initial step in the transfer of technology process is the recognition of a need. This need must be satisfied by current technology applied differently, or it must be satisfied by new technology. Needs can arise from the following.

- Scientific changes
- Competition
- The market
- Legislation
- Human inquisitiveness
- Innovation as company policy

Scientific changes can bring about new products, utilizing new technologies. An example would be the development of nylon, which made it possible to solve needs in a technologically advanced way.

Competition together with the market may be one of the greatest initiators of the need to transfer new technology. The market is becoming increasingly fragmented and more sophisticated. This means that an organization's products or services must be tailored to address the specific needs of individuals. If an organization does not have the technological capability to do so, it will lose that market to its competitors. Technology can give a business the competitive advantage it needs, to secure its position in the market.

Legislation may also create a need that has to be solved by obtaining new technology. If we think about the aviation industry in general there are, for example, restrictions on the noise levels of aircraft over populated areas surrounding airports. This legislation disqualifies older aircraft from using these airports. A new need arose and subsequently engine noise was reduced by developing 'hush kits', which at that stage was a new technology in the aviation industry. Human inquisitiveness together with innovation as company policy (R&D), always ensures advances in technology.

Searching for technology

After defining a need, an organization must search for appropriate technology that will best satisfy the need. There are several strategies that can be followed and they can be divided into two major groups. The first is developing the technology yourself and the second is looking for the technology outside the organization. We will look in more depth at the second case.

Information plays a big role in the search for new, or the most applicable technology. Organizations are particularly interested in information on products, research activities, finance and patent information. One of the successful sources of information and co-operation is higher education institutions in the form of universities. Partnerships with these institutions help companies to:

- Access new technologies
- Keep abreast of new technologies
- Access consultancy skills
- Develop new technologies jointly

The transfer of technology from university to industry can be established in several ways. One must keep in mind that knowledge, which is part of technology as explained in the introduction to technology transfer, is part of a person and resides in their mind. Therefore technology can be transferred through the movement of people.

The first of the transfer mechanisms is graduate employment. At university level people build up a knowledge base in their respective field and this knowledge base is then transferred to industry by employing that person. Industry will often make grants available for people to complete their university studies. In this way they assure a smooth transfer process. A second mechanism is through sabbaticals. Sabbaticals enable university lecturers to work in a company. This is a reciprocal transfer mechanism. The lecturer's knowledge is exploited in the company and the university is exposed to the industry, through the lecturer's practical experience. Further very successful and often used mechanisms include consulting services offered by the universities, contract research, industry/university research units, university or industry liaison units and forums for the exchange of information.

Another major source of information and assistance is technology transfer agencies. These agencies offer a wide variety of services from searches on information, products and patents, to legal advice and consultancy. These agencies can be very useful for some of them specialize in certain industry areas and therefore have extensive knowledge in that area of industry. For an organization that does not have specialized skills in the area of technology transfer, this is an excellent alternative to consider. In some cases an external party has a more objective view on the industry and can therefore deliver a more objective opinion, as opposed to individuals inside an industry.

A tremendous amount of research goes into universities, research bodies and industry. For any organization it is essential that this research be exploited and transferred, in order to strengthen their technological function. Organizations that do not have the capability of doing their own research should seriously consider partnering with these institutions, in order to have access to relevant research.

Evaluating the Technology

When identifying technology it should be evaluated in order to find the most suitable technology. Aspects that should be addressed in the evaluation process include:

• Strategic implications

• Effect on market and customer

• Operational changes

• Personnel

• Training

Before starting the transfer process an evaluation criterion should be defined in order to evaluate each identified technology. The team responsible for the transfer of the technology, should define aspects to be evaluated and the measurement criteria for each aspect. It is important to involve as many people as possible, especially those that will work with or will be effected by the new technology. By involving all concerned, an objectively defined opinion should be possible and the most appropriate technology can be selected. It must be stressed that the evaluation criteria should consist of objectives and specifications already defined, after the identification of the need. This will aid in the transfer process, for each aspect in the transfer process will be measured or evaluated according to the defined criteria.

Transfer

Transfer of technology takes place via certain mechanisms. These mechanisms can be identified per area of technology as follow.

Technology in the form of knowledge can be conveyed through the following mechanisms:

- In print through technical journals
- In print through learned journals
- Scientific magazines
- Patents
- Orally at conferences
- Orally at learned societies
- In discussions with colleagues
- In discussions with acquaintances
- In discussion with consultants
- On television or radio
- Courses
- Service bulletins
- Data packs
- Specifications

Technology in the form of skills is acquired by doing something. It can be conveyed by:

• Watching someone doing something

• Watching a video of someone doing something

• Demonstrations at courses

• Hands on training

Technology in the form of equipment is conveyed via the following mechanisms:

• Products

• Trade magazines

• Trade conventions

• Sales representatives

• Advertisements

• Direct mail

• Contacts in other companies

Company-to-Company Transfer

It is clear that the collaboration between companies is the major technology transfer mechanisms in the private to private domain. There are several forms of collaboration, but for the purpose of this research we will focus on technical collaboration. One form of technical collaboration is where partners increase their expertise through sharing knowledge, skills and equipment. Another form is where one partner is in possession of technology, which the other needs for it's new product. Cooke and Mayes5 identified the main aims of collaboration between companies as follows:

- Sharing risk
- Sharing cost
- Growing of technological knowledge
- Helping in product development
- Developing industry standards together
- Acquiring and/or penetrating new markets
- Improving speed to market

Developing new products is a risky and costly business and therefore companies will rather share the risk and cost involved in these projects. Companies also feel more assured if they concentrate on a business area they are familiar with, while leaving other aspects to partners that are more familiar with business in those areas.

Modes of Transfer

All transfer models can be divided into two major categories. The first category is passive and the second is active This classification refers to the level of activity in applying the technology in the transfer process. If the technology transfer mechanism presents the technology to the potential user, without assistance regarding it's application, then the mode is said to be passive. In the passive mode only the knowledge part of technology is transferred. The skills surrounding the technology are not transferred. These mechanisms can include presentations in a report. If, on the other hand the provider of the technology assists with the application of the technology, then the mode is said to be active. These mechanisms include training, etc. The boundaries between passive and active are not easy to define and therefore a semi-active mode is also defined.

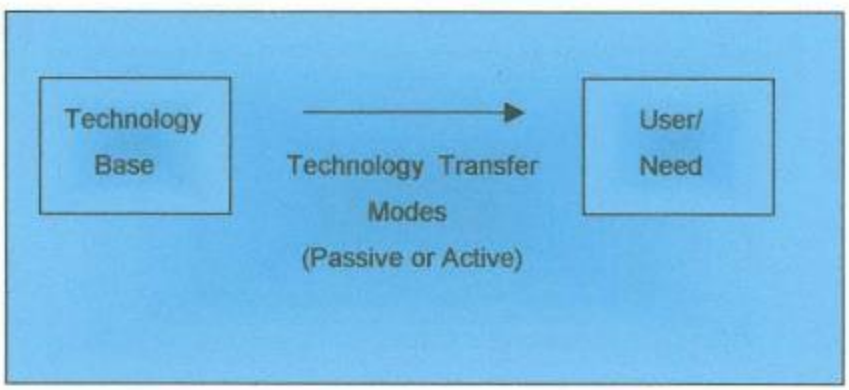


Figure : Transfer modes

Passive Mode

The most widely used mechanism in the passive mode is the instruction manual or "cookbook" approach. This is the only contact between the originator of the technology and the user. Millions of products are made and sold with transfer occurring in this form. Just think of one's own motor car. These self-teaching manuals used in this mode all have one thing in common: they presume that the user has some level of knowledge and competence in the specific technological area. It is an important point in this mode of transfer. A mechanic can assemble a component perfectly from an instruction manual. This becomes more intricate when we think of other technologies like glassblowing, sheet metal work and woodwork. In these areas the skill that lies with the user must be far greater. This is important to keep in mind if you want to transfer technology. The skill resting in the user of the technology must be clearly defined by the originator, because this will have a definite impact on the success of the transfer process. If you give someone who does not know how to drive a motor car, that technology, it will be useless to the person, because it cannot be used.

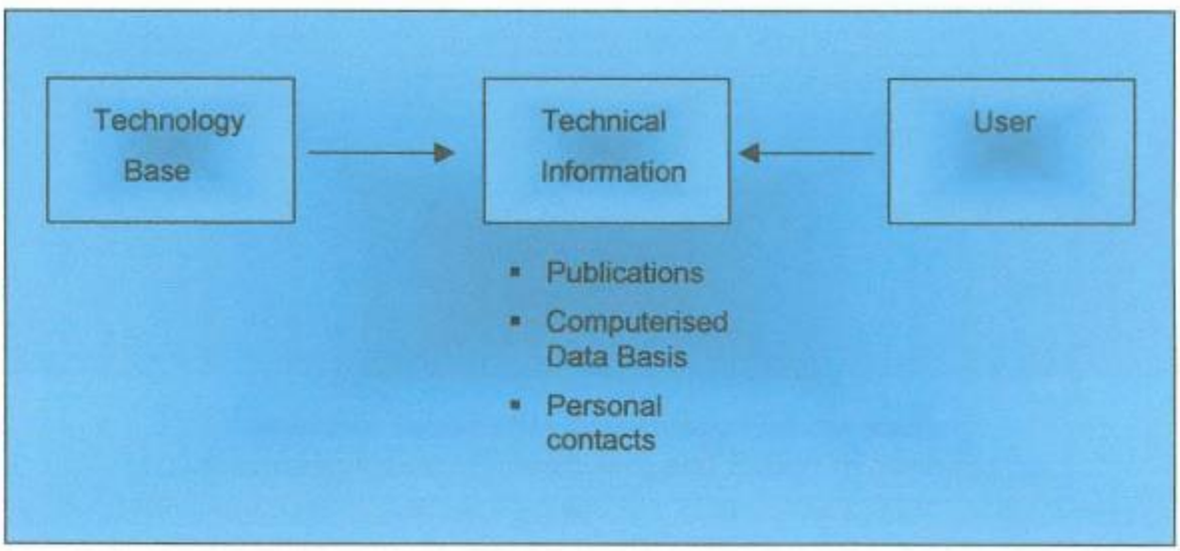


Figure : Passive Technology Transfer Mode

Semi-Active Model

In the semi-active mode there is intervention from a third party in the transfer process. This is usually in the form of a transfer agent. In the semi-active mode the role of the transfer agent is limited to that of adviser. Very often in the semi-active mode, the transfer agent only screens information in the relevant field of interest and passes it on to the final user. He therefore ensures the relevance of the information, because of his knowledge, not only about the user's needs, but also because of his knowledge about the technology. The role of the transfer agent is therefore one of communicator between the technology and the user. If his role is beyond this, then the mode of transfer becomes active.

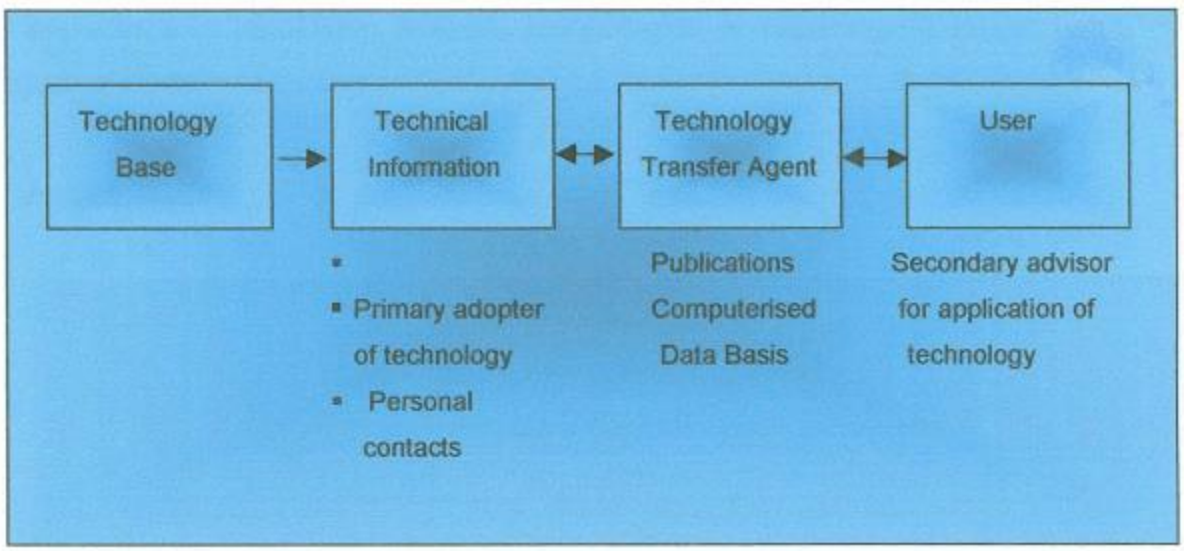


Figure : Semi-Active Technology Transfer Mode

The most widely used source of technical information is in the form of written technical documentation and therefore the passive mode of transfer is the most widely used. Because of this, care should be taken in the writing of these documents. Very often data banks and published material are searched in order to obtain information on relevant subjects. Experience has shown that what the first would-be user wants to read is a non-technical description of the technology. Because the reader will be trained in one or more technical disciplines, it will be easy for him to judge the relevance of the document. Because of the increasing amount of data this becomes more relevant. This is a time consuming effort and often it is 'outsourced' to a transfer agent. He will then be responsible for identifying relevant information and transferring it to the user. The transfer agent can be in the form of one or several people working in a team, each within their own field of expertise. An additional benefit of using a transfer agent, is that the user of the technology may have interpreted the problem incorrectly and this is leading them along the wrong path in their search for a solution. Here the agent can be of help because of his knowledge of the user's needs.

The passive and semi-active modes are therefore recognized by the fact that no third party participates in the application of the technology. Only limited assistance in identifying relevant technologies is experienced in the semi active mode.

Active Mode

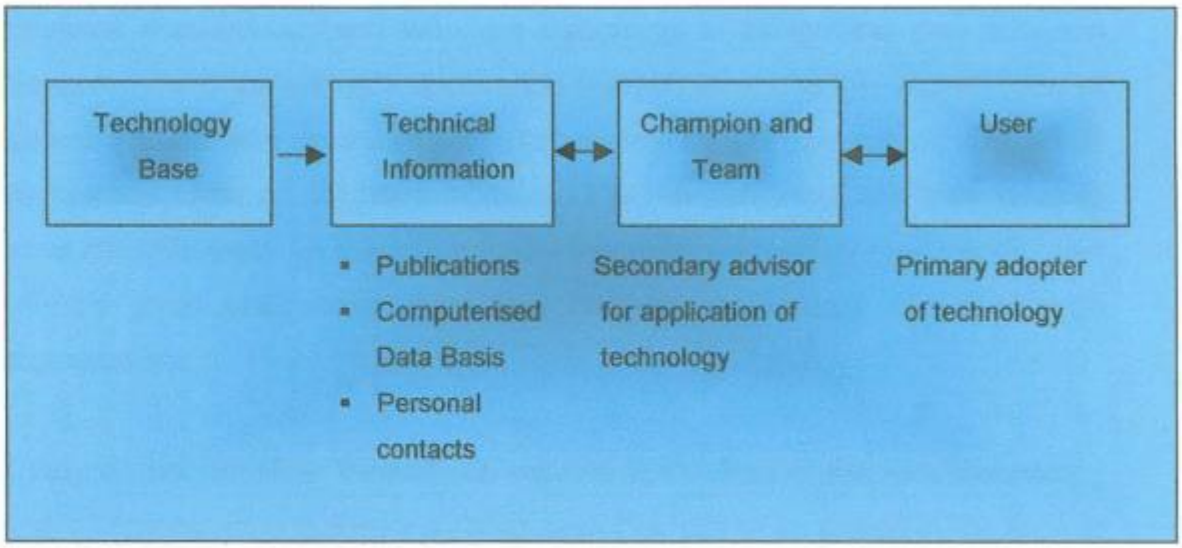


Figure : Active Technology Transfer Mode

APPENDIX I

CONTENT BEYOND THE SYLLABUS

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CONTENT BEYOND THE SYLLABUS

NON CONVENTIONAL SOURCE OF ENERGY

GEOTHERMAL ENERGY

What is Geothermal Energy?

Geothermal energy is the thermal energy generated and stored inside the Earth's crust. The center 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'. When underground water comes in contact 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.

Geothermal energy

In order 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.

Applications

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.

1. Farming: In cold countries, geothermal energy is used to heat greenhouses or to heat water that is used for irrigation.
2. Industry: Geothermal energy is used in industries for the purpose of food dehydration, milk pasteurizing, gold mining, etc.
3. 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

- 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 laborers 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 the 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

- 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 resources.
- 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 on 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.

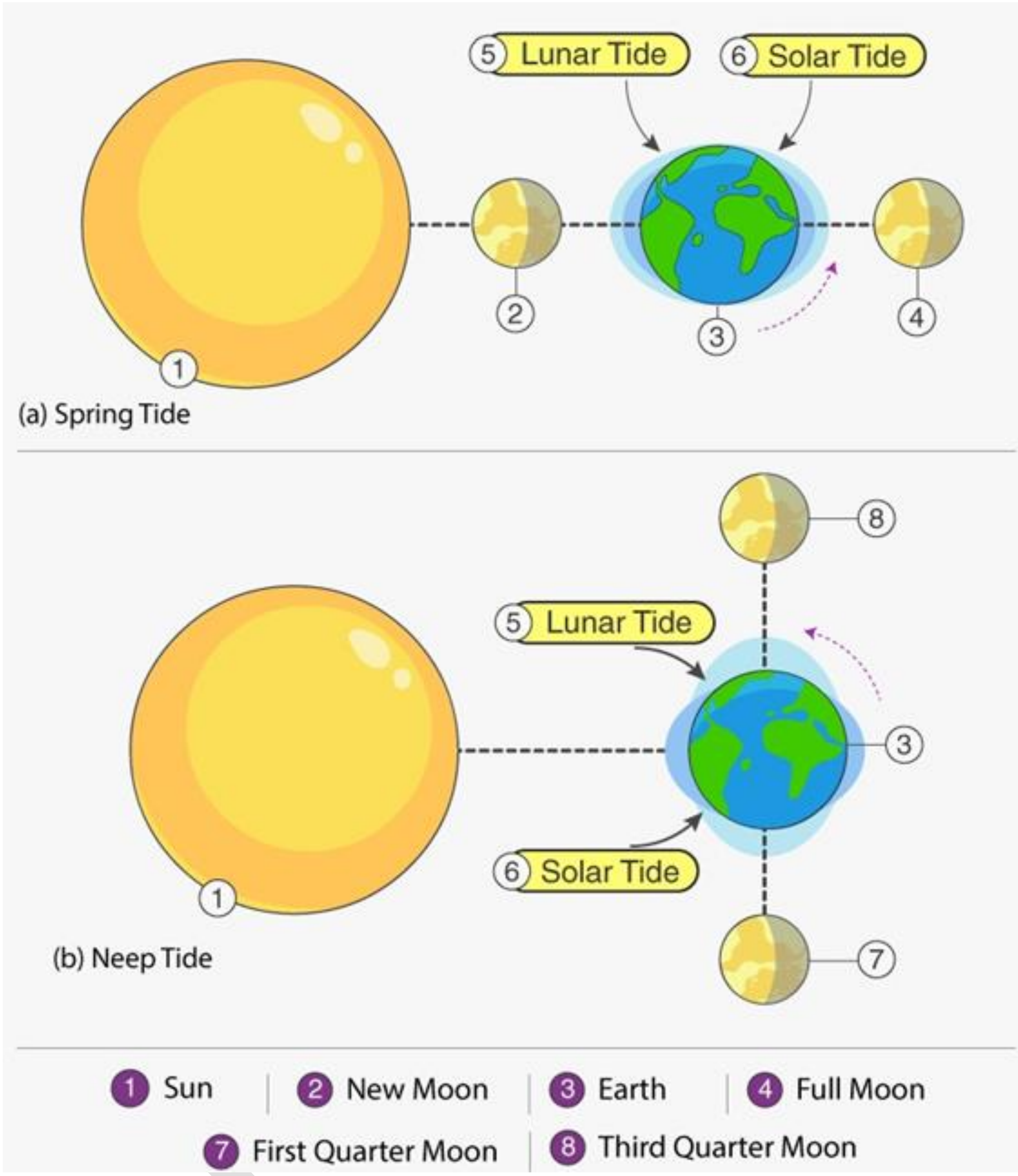
TIDAL ENERGY

Energy is required for the evolution of life forms on earth. However, a significant portion of the energy which we use today is obtained from non-renewable sources. This implies that once they are used up, they cannot be replenished. The most important source of non-renewable energy used extensively is fossil fuels which have taken millions of years to be formed. Thus, it is important to use them judiciously. This requires us to look for alternate sources. We know that energy exists in different forms in nature and that it cannot be created or destroyed. But it can be transferred from one form to another. The energy from nature- the sun, the wind, waves, tides, etc. can be converted into a usable form. One of these renewable sources of energy is tidal energy.

What are Tides?

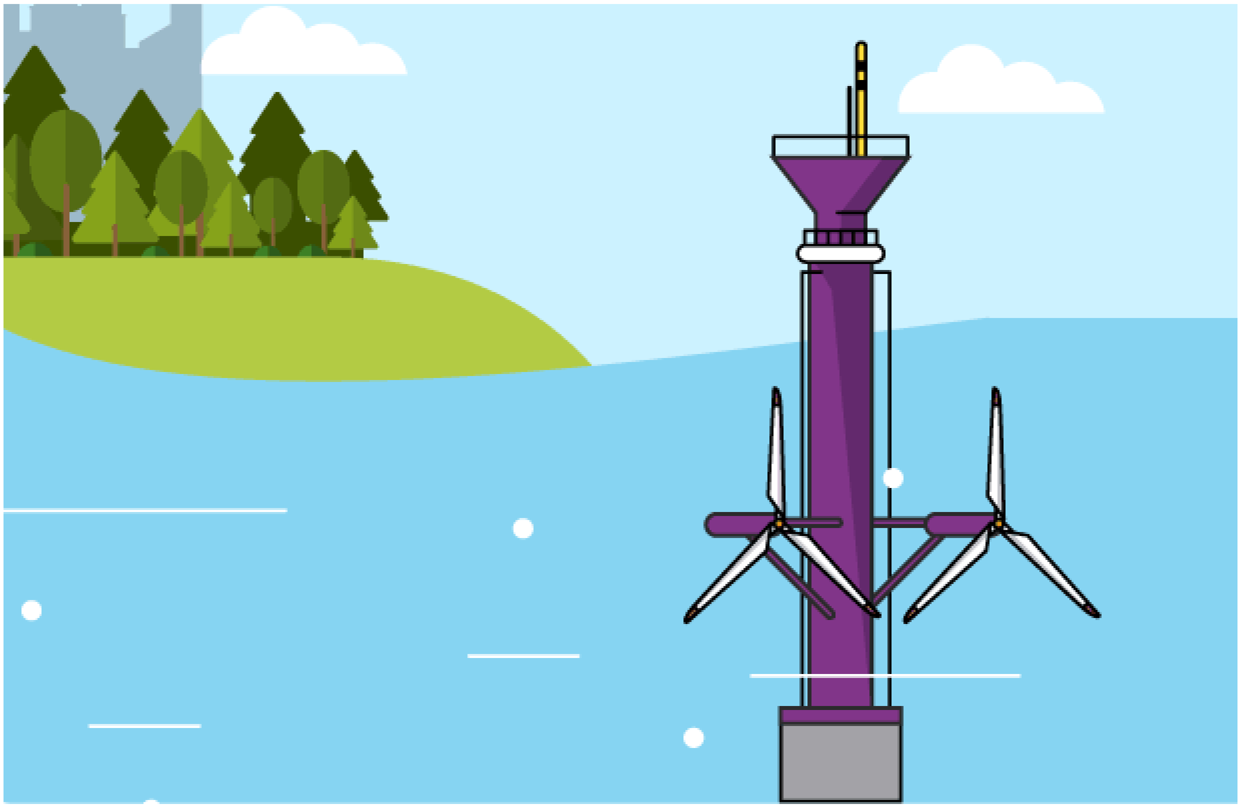
The gravitational forces of the sun and the moon combined with the rotation of the earth result in an alternate rise and fall of the sea levels. At one particular place, it usually occurs twice on a lunar day. The rise of the sea level is called the high tide, whereas the fall is called the low tide. When the earth and moon's gravitational field are in a straight line, the influences of these two fields become very strong and causing millions of gallons of the 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 seawater, thereby resulting in weak tides. These weak tides are known as neap tides. Neap tides occur during the quarter moon phase.



What is 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.



Tidal Energy Generator

Tidal Energy Generator

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.

Advantages and Disadvantages of Tidal Energy

Some advantages of tidal energy are:

- Environment-friendly
- A highly predictable energy source
- High energy density

- Operational and maintenance costs are low
- An inexhaustible source of energy

Some of the disadvantages of tidal energy are:

- High tidal power plant construction costs
- Negative influence on marine life forms
- Location limits
- The variable intensity of sea waves

Although not widely used, tidal energy has the potential for future electricity generation. Among other sources of renewable energy tidal energy has suffered due to the relatively high cost and limited availability of sites for construction. However, due to the recent technological developments indicating that the economic and environmental costs can be brought down to competitive levels, there seems to be a bright future for tidal energy generation.