بسم الله الرحمن الرحيم

ISLAMIC UNIVERSITY OF TECHNOLOGY

The Organization of Islamic Cooperation (OIC)

Department of Technical and Vocational Education (TVE)

Wind Energy: Energy Sustainability Perspective

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE IN TECHNICAL AND VOCATIONAL EDUCATION IN ELECTRICAL & ELECTRONIC ENGINEERING

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Dedication

This study is dedicated to our parents

Declaration

We do hereby declare that this report has not been submitted elsewhere for obtaining any degree or diploma or certificate or for publication.

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Preface

Energy is the capability to do work. No work can do without energy. Energy is such prerequisite for, '*economic development'* of a country as well as for the improvement of, *'quality of life'* of its population. The United Nations' General Assembly accordingly adopted and declared, "*2014 and 2024 as the decade of sustainable energy of all*".

There are many forms of energy e.g. heat, light, biomass, fossil fuel, sound etc. Out of all these forms, '*electricity*' is the, '*most preferred form'* as it is clean, extremely fast and can be converted to the most other form easily and efficiency. Natural nonrenewable oil and gas are primarily used in transportation and industry.

The economic development of a country is much dependent on the availability of quality electricity at an 'affordable price' the gross domestic product (GDP) of a country depends on the capita consumption of primary energy. The per capita annual average electricity consumption of the developed and or OECD countries are more than 10000kWh while that of 'least developed countries' per capita annual electricity consumption rate is less 500kWh.

Electricity is however not naturally available. It has to produced from '*primary sources'* available in nature. Primary source are generally grouped under two basic types i)'*renewable energy*' e.g., solar, wind, tide etc whose supply is not affected by rate of use; and ii) *Non renewable energy* e.g., coal, oil gas, nuclear, fuel etc. whose supply or reserves are affected by the rate of use.

Currently about 67% of the global electricity is generated from non renewable coal, gas and oil. The total use of coal, oil and gas are about 6.3 million tons, 4 billion tons and 3.8 trillion m^3 respectively. The rate of consumption is increasing. This is not sustainable as the trend will deprive the prosperity from primary energy sources.

Hydro power- a renewable source, which is presently considered not environment friendly, generates about 14% of the global electricity and the remaining on 4% of electricity is produced using all other renewable energy source.

Burning of fossil fuel in power station and other economic activities e.g. transportation emits about 40 billion tons of green house gases annually causing '*climatic changes*. The emission of enormous amount of SOx and NOx are causing '*acid rain'*. Burning of coal is polluting underground water with deadly *'arsenic'* and *'lead'* air with 'particulates' putting the present generation as well as the future generation into serious health risk. This is not sustainable

Renewable energy source wind available throughout the world. Use of wind is the most free from pollution of green house gases and other pollutant stated in the preceding paragraphs. The greater use of wind in the energy mix as such can help in achieving the goal of energy sustainability

Majority of the members states *Organization of Islamic Cooperation (OIC)* either fall in the category of the '*least developed'* or in the *'developing states'.* These states are situated in either in tropical or subtropical regions. Some of these states have even desert areas and also borders with sea or oceans where the average wind velocity is high. Wind is available throughout the world independent of altitude or latitude.

Wind turbines can be set up in the states to generate electricity and the medium electricity demands of domestic, commercial and industrial consumer preferably with hybrid systems. Electricity generated by wind turbines in the desert, sea or isolated area can be fed into power transmission grid networks. This will help in achieving the goal energy sustainability.

The use of wind turbines for generating electricity will also diversify the use of primary energy source and will fulfill the objective of conservation of primary sources. It may reduce the overall electricity generation cost.

But the materialization of useful and economic wind turbine power systems will require commitments, study and analyses of the local realities, proper planning road map continued efforts by the state policy makers and responsible implementing bodies or organizations.

The special study *"wind energy; energy sustainability perspective"* carried out effort to gather knowledge and ideas on wind technology and wind power generation systems consisting of turbines generators, towers, converters, inverters battery bank, sensing and protecting devices, wind related hybrid power generation system etc. Effort have also been carried out to study and get ideas on the past, present and future trends of developments, economics and technical feasibilities in providing electricity to meet the electricity demands of the states under optimum energy mix. The report presents findings of the study and analyses of the topic

1. Introduction

Objective

Wind Energy: Energy Sustainability perspective; provides analytical background and scientific information regarding to the growth and development energy. It furthers describes energy's fundamental relationship to sustainable development and how are the goals are achieved effectively whereby it's acting as instrument. The introduction shows the clear flow of chapters.

Organization

In order to analyze this special study, we have to get familiarized with the scenario; Energy, Electricity and Human development, benefits of wind energy, materials, methodologies used to convert wind energy into electricity, and this can be achieved organizing the report, following the chapters below,

The second chapter describes the Key terminologies throughout the collection and organization of the data.
Chapter three consists of the general overview of Energy, Types, Primary Source, Energy Security, Energy Sustainability, Energy Accessibility and Global warming and Environmental pollution.

The forth chapter; Electricity and human development index, Showing the various trends energy development, demonstrating the commercial and economic viability of the technology and industry, human and development Index and the gross development product plus per capita income of different countries.

The fifth chapter, Electricity generation describes the primary sources that is renewable and non renewable, environment and climatic effects plus past and future trends.

Chapter six, Wind energy showing the history from the past centuries up to the latest, the physics and the various types of technology development it has gone through.

Chapter seven, System design relating to the various data collected of wind flow all over the world, calculation of speed of wind, the different types of materials used including the turbine, converter, inverters, towers and the generators, codes and standards, environmental issues and the economic cost with respect to the other forms.

Chapter eight, Application that is on grid system and Hybrid transfer

Chapter nine, Leading countries: United States of America, Germany, India, China and Spain showing how these countries have developed in line with the progress of Wind Energy.

Chapter ten describes the analysis and synthesis the data collected from the participant member countries that is Uganda, Somalia and Yemen.

Chapter eleven, key findings shows conclusion made regards the data obtained from the participant countries, and the applicability of the Wind power,

Chapter twelve, conclusion and recommendation, depending on the key findings we shall give conclusions as result of application, cost, environmental issues regarding wind energy growth and development in the participant countries.

2. Key Terminologies

Wind energy: Energy Sustainability Perspective is huge topic of study, through the key terms listed and defined in this study.

Adequacy: a measure of the ability of the power system to supply the aggregate electric power and energy requirements of the customers within component ratings and voltage limits, taking into account planned and unplanned outages of system components. Adequacy measures the capability of the power system to supply the load in all the steady states in which the power system may exist, considering standard conditions.

Availability: Describes the amount of the time that the wind turbine is actually functional, not out of order or being serviced.

Balance Of Plant (BOP): the infrastructure of a wind farm project, in other words all elements of the wind farm, excluding the turbines. Including civil works, SCADA and internal electrical system, It may also include elements of the grid connection.

Black Start Capability: some power stations have the ability to start up independently of a power grid. This is an essential prerequisite for system security, as these plants can be called on during a blackout to re-power the grid.

Capacity: The rated continuous load-carrying ability of generation, transmission or other electrical equipment, expressed in megawatts (MW) for active power or megavolt-amperes (MVA) for apparent power.

Capacity Factor: The ratio between the average generated power in a given period and the installed (rated) power.

Cogging: Refers variation in speed of a generator due to variations in magnetic flux as rotor poles pass stator poles. Cogging in permanent magnet generators can hinder the start-up of small wind turbines at low wind speeds.

Community Acceptance: Refers to the acceptance of specific projects at the local level, including affected populations, key local stakeholders and local authorities' control.

Darrieus Rotor: Sleek vertical axis wind turbine developed by French inventor G. J. M. Darrieus in 1929 based on aerodynamic profiles.

Decibel (dB): unit of measurement that is used to indicate the relative amplitude of a sound or the ratio of the signal level such as sound pressure. Sound levels in decibels are calculated on a logarithmic scale.

Diffuse: Downwind device that diffuses the wind stream through a rotor.

Direct Drive is a drive-train concept for wind turbines in which there is no gearbox and the wind turbine rotor is connected directly to a low-speed electrical generator.

Distributed Generation: Single or small clusters of wind turbines spread across the landscape, in contrast to the concentration of wind turbines in large arrays or wind power plants.

Doppler Shift Principle: when a source generating waves moves relative to an observer, or when an observer moves relative to a source, there is an apparent shift in frequency. If the distance between the observer and the source is increasing, the frequency apparently decreases, while the frequency apparently increases if the distance between the observer and the source is decreasing. This relationship is called the **Doppler Effect (or Doppler shift)** after Austrian physicist Christian Johann Doppler (1803–1853).

Efficiency for a turbine describes the amount of active electrical power generated as a percentage of the wind power incident on the rotor area.

Emissions are the discharges of pollutants into the atmosphere from stationary sources such as smokestacks, other vents, surface areas of commercial or industrial facilities, and mobile sources such as motor vehicles, locomotives and aircraft. With respect to climate change, emissions refer to the release of greenhouse gases into the atmosphere over a specified area and period of time.

Energy Service: the term used to describe the benefits offered to the consumer by energy system like in households include, illumination, cooked food, comfortable indoor temperatures refrigeration and transportation plus commercial and industrial services

Energy Security is a term for an association between national security and the availability of natural resources for energy consumption. Access to cheap energy has become essential to the functioning of modern economies. However, the uneven distribution of energy supplies among countries has led to significant vulnerabilities.

Energy Sustainability is the sustainable provision of energy that meets the needs of the present without compromising the ability of future generations to meet their needs that is projection of thirty to fifty years. Technologies that promote sustainable energy include renewable energy sources, such as hydroelectricity, solar energy, wind energy, wave power, geothermal energy, artificial photosynthesis, and tidal power, and also technologies designed to improve energy efficiency.

Energy Payback is the time period it takes for a wind turbine to generate as much energy as is required to produce the turbine in the first place, install it, maintain it throughout its lifetime and, finally, scrap it. Typically, this takes 2–3 months at a site with reasonable exposure.

Equivalent Sound Level (dBLeq) quantifies the environmental noise as a single value of sound level for any desired duration. The environmental sounds are usually described in terms of an average level that has the same acoustical energy as the summation of all the time-varying events.

Full Load Hour Refers to turbine's average annual production divided by its rated power. The higher the numbers of full load hours, the higher the turbine's production at the chosen site.

Generation Mix is the percentage distribution by technology (nuclear, thermal, large hydro,

Rated Wind Speed is the lowest steady wind speed at which a wind turbine can produce its rated output power.

Reinvestments are the costs of replacing a larger and more costly part of a turbine.

Reliability describes the degree of performance of the elements of the bulk electric system that results in electricity being delivered to customers within accepted standards and in the amount desired. Reliability at the transmission level may be measured by the frequency, duration and magnitude (or the probability) of adverse effects on the electric supply/transport/generation. Electric system reliability can be addressed by considering two basic and functional aspects of the electric system that is adequacy and security

Savonius Rotor (S-rotor): a simple drag device producing high starting torque developed by the Finnish inventor Sigurd J. Savonius.

Security Limits define the acceptable operating boundaries (thermal, voltage and stability limits). The TSO must have defined security limits for his own network and must ensure adherence to these security limits. Violation of these limits for a prolonged period of time could cause damage and/or an outage of another element that could cause further deterioration of system operating conditions.

Small Wind Turbine (SWT): a system with 300m^2 rotor swept area or less that converts kinetic energy in the wind into electrical energy.

Tip Speed: speed (in m/s) of the blade tip through the air.

Transformer: a piece of electrical equipment used to step up or down the voltage of an electrical signal. Most turbines have a dedicated transformer to step up their voltage output to the grid voltage.

Turbine Lifetime: Refer to expected total lifetime of the turbine (normally 20 years).
Turbulence Intensity measures the 'roughness' of the wind, calculated for a time series of wind speed data, as the standard deviation divided by the mean wind speed.
Wind Home System (WHS): a wind-based system to provide basic lighting and entertainment needs to an individual home, with a capacity typically in the range of hundreds of watts.

3. Energy

Energy is the ability to do work; various forms of energy have to be considered such that it's accessible and sustainable. Therefore the forms which discussed below are ensured that there are converted to a form that is most required for economic development as well as improvement of the quality of life.

3.1 **Types**

Energy can take several forms depending on the service is to deliver such as heat energy, light energy, electrical energy, mechanical energy, nuclear energy, chemical energy, elastic energy, sound energy. But the main types of energy are:

Kinetic energy, potential energy, chemical energy, nuclear energy, electrical energy, heat energy.

3.1.1 Kinetic Energy

Kinetic energy is the energy that is in motion also it's defined that the work needed to accelerate a body of a given mass from rest to its stated velocity.

There are many forms of kinetic energy such us:

Mechanical energy, electrical energy, thermal energy, sounds energy all of them are kinetic energy.

Kinetic Energy = $\frac{1}{2}mv^2$

Kinetic energy also can be converted into other types of energy.

3.1.2 Potential Energy

Potential energy is the energy stored in an object. This energy has the potential to do work. Gravity gives potential energy to an object.

This potential energy is a result of gravity pulling downwards.

Gravitational Potential Energy

The potential energy acquired by an object by virtue of its height above the earth is called gravitational energy.

When you take an object above the earth level work is needed to do that against the force of gravity. The amount of work to be done, as per definition of work, is force × distance, which in turn is mass of the object × acceleration due to gravity× height to which the object carried up. That is algebraically,

$P=m\times g\times h$

Where 'P' is the potential energy of an object of mass 'm' at a height h from the ground and 'g' is the acceleration due to gravity at that place.

Elastic Potential Energy

Suppose an object is either compressed or stressed due to a force. An object is supposed to be elastic when it retains the original shape after the force is removed. The force that is applied on the object is stored as its 'elastic potential energy' which helps the object to restore its initial position.

A spring is an elastic object that can be compressed or stretched on applying a force and the amount of stretch or compression is called the displacement. The force required to do this work is given by, **Hooke's Law** as,

$F = k.dx$

Where, dx is the measure of displacement and 'k' is a constant known as **spring constant**.

However, the average force requires for the displacement is F_2. Hence the work done for the displacement is,

$F_2x = 12kx^2$

Which is stored as the elastic Potential Energy of a spring.

Electromagnetic Potential Energy

Some objects can be electrically charged due to electron movements on the surface under some conditions. Such objects under charged condition create an electromagnetic field which tends to oppose any other electrical charge and this ability to oppose is called electromagnetic potential energy of the initial charge.

With some objects the surface electrons can be rearranged too and subsequently the objects get electrically charged. Under such conditions they form a field of force called electromagnetic field. The strength of this electromagnetic field depends on the amount that has been charged. This field opposes any other charge to come closer to it. Thus the object acquires a potential energy capable of repulsing a similar charge. This type of potential energy is called as the electromagnetic potential energy of the object. When another electrical charge into this field, work has to be done against the force of the same field.

Let us assume that the object is charged to a unit of q_1. Suppose another charge of magnitude q_2 is brought closer at a distance d, the force F exerted by the field of q_1 on q_2 is given by Coulomb's law as,

$F = kq_1q_2d_2$

Where 'k' is a constant.
The work done dw against the electromagnetic field to move the charge at distanced from the first charge is, d_W=-Fdr=−(k×q_1×q_2)d_2 dr,
The negative sign is due to the fact that the force is opposing.
Therefore, the total work done from infinity to a distance d is, W=∫d∞dW=(k×q_1×q_2)dr
This is the electromagnetic potential energy of the charge q_1.

Nuclear Potential Energy

Some objects have the property of radiating light and heat. Such objects are called radioactive elements. For example, you see a bright light when radium is kept in dark. But not all radio elements exhibit this property.

All materials have nuclear structure as per atomic theory. The nuclear particles are held together by a force called nuclear force. The energy which is capable for this holding force is called nuclear potential energy. In cases like radium the energy binding the nuclear particles is a Weak Nuclear Potential Energy. That is, the nuclear particles get released by themselves. In other cases, the energy is called Strong Nuclear Potential Energy. But, after a lot of research by scientists it has been found that even the strong nuclear potential energy can be released by nuclear reactions and the energy released can be used in several ways. An atomic power plant generates electrical energy based on this concept.

3.1.3 Electrical Energy.

Electrical energy is the energy carried by moving electrons in an electric conductor. That is every atom is considered to be consisting of clouds of charged particles, electrons, moving constantly around the central nucleus.

All matter consists of atoms, and every atom contains one or more electrons, which are always moving. When electrons are forced along a path in a conducting substance such as a wire, the result is energy called electricity.

Electrical generating plants do not create energy. They change other forms of energy into electricity. For example, power plants can convert chemical energy stored in fuels into thermal energy, which evaporates water into steam, which produces mechanical energy as it moves through turbines. The turbines spin generators, which produce electricity.

3.1.4 Chemical Energy.

Viewed at atomic level can considered as form electrical energy where fuels are burn, chemical energy stored is released in a chemical reaction, form of heat. Such reactions are called exothermic**.** Batteries, biomass, petroleum, natural gas, and coal are examples of stored chemical energy. For example, when an explosive goes off, chemical energy stored in it is transferred to the surroundings as thermal energy, sound energy and kinetic energy.

3.1.5 Nuclear Energy.

Nuclear energy is a form energy that is bound up at the central nuclei of the atom, originated during the second world war after the technology released for military purpose(Einstein’s famous formula $E = mc^2$), from the splitting of uranium atoms in a process called fission. At the power plant, the fission process is used in peaceful way to generate heat for producing steam, which is used by to drive the turbine to generate electricity.

The sun can also be used as the source of nuclear energy whereby in this case it’s considered as nuclear fusion not fission that is enormous quantity of hydrogen atoms fuse to form helium atoms, generating massive amount of solar radiation in the process. The process of generating electricity by imitating sun to produce nuclear reactors is the subject of research.

3.1.6 Heat Energy.

Heat energy - a form of energy that is transferred by a difference in temperature, Heat (Thermal energy) Thermal energy is what we call energy that comes from heat.

3.2 Primary Energy

Primary energy is an energy form found in nature that has not been subjected to any conversion or transformation process. It is energy contained in raw fuels, and other forms of energy received as input to a system. Primary energy can be non-renewable or renewable.

The primary energy sources are derived from: the sun, the earth's heat, the wind, water (rivers, lakes, tides, and oceans), fossil fuels - coal, oil, and natural gas, biomass, Most of the primary forms of energy are not directly useful to us. Fuels we use every day, electricity and gasoline for example, are not listed. These are secondary forms of energy, also known as energy carriers, and they need to be made using these primary energy sources. Even natural gas, commonly used to heat our homes and cook our meals, needs some processing before it can be used as a fuel for your home. Secondary energy sources will be explored in the next section.

Most of the energy we use today comes from the nonrenewable fuels- oil, natural gas, coal and uranium - our source of nuclear energy.

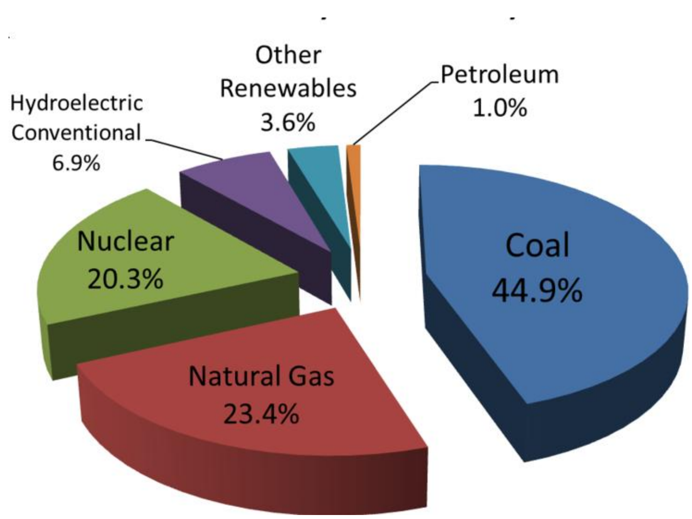

Fig 3.1 primary energy source

www.eia.gov/cneaf/electricity/epa

3.3 Non Renewable Energy

A non-renewable energy refers to the energy derived from natural resource which cannot be reproduced, grown, generated, or used on a scale which can sustain its consumption rate; once depleted there will be no more available for future use(its affected by its rate of use). Also considered non-renewable are resources that are consumed much faster than nature can create them. Fossil fuels (such as coal, petroleum, and natural gas), nuclear power (uranium) and certain aquifers are examples. Metalores are prime examples of non-renewable resources

3.4 Renewable Energy

Renewable energy is energy that is generated from natural processes that are continuously replenished (the source is not affected by the usage). This includes sunlight, geothermal heat, wind, tides, water, and various forms of biomass. This energy cannot be exhausted and is constantly renewed [1].

3.4.1 History

Renewable source arise as result of solar power that is in form of direct solar radiation or indirect forms

We live in a world dominated by oil, a commodity whose true costs are rising every day. Scarcity of cheap oil, spills, lung disease, pollution, wars, and the empowerment of terrorist regimes all combine to make one thing obvious to all: unless you're an oil company, you need to be an advocate for alternative forms of energy – preferably clean, renewable energy. But how much do we really understand about these alternatives?

3.4.2 Types

The global battle against climate change has encouraged both developed and developing nations to reduce carbon dioxide emission. Signatories of the Kyoto Protocol lead the world to emission reduction activities, one of which is conducting research and development on renewable energy. Here are some of types of renewable energy sources that are being considered to power the globe in the nearest future.

1. Solar Energy

Solar energy refer to the form of energy that is converted electricity either directly using solar PVs (Photovoltaic) or indirectly using concentrated solar power,

Solar Photovoltaic (**PV**)where electricity is generated by converting solar radiation into direct current electricity using semiconductors

It basically produces energy by using microchip-like materials that absorbs sunlight. This frees the electrons from their atoms and allows them to generate electricity. PV cells are generally reliable and produce less to none pollution and easy to maintain [1].

Solar thermal technology (Concentrated Solar Power)

Concentrated Solar Power system uses lenses or mirrors and tracking system to focus a large area of sunlight in small beam.

Solar thermal systems, as the name implies, also derive energy from sunlight. The system uses solar collectors to absorb solar radiation that will then be used to heat water or air that will generate steam used to operate a turbine. The turbine will then power a generator [1].

Federal and state government encourages citizens to install solar energy at home or in the workplace by awarding income tax credits. The same is being done for the other six types of renewable energy sources.

2. Biomass

Biomass is biological material derived from living, or recently living organisms. In the context of biomass for energy this is often used to mean plant based material, but biomass can equally apply to both animal and vegetable derived material [1].

The International Energy Agency reports that 11% of the world's renewable energy is derived from biomass. The technology produces 7,000 megawatts of renewable electricity. Biomass is taken from industrial processing of forestry and wood products, agriculture, construction and solid waste. These biodegradable materials are converted to gas by burning it in a gas turbine. In the United States, mill operations are the main source of biomass energy. It is the best alternative to coal as it produces less sulfur dioxide.

3. Hydroelectric Power

Hydroelectric source depends on the natural evaporation of water by solar energy. Hydro power is the process of changing the kinetic energy of flowing water in a river into electrical power that we can use.

Hydropower is the largest source of renewable energy. Its generating capacity amounts to 77,000 megawatts. Water coming from rivers and waterfalls are released through turbines to produce energy. Although the technology is non-pollutant, it can possibly harm marine wildlife as it may alter the quality of water. Other than that, hydropower is also highly expensive and is likely to take a long time to install [1].

ADVANTAGES

- No pollution or waste produced
- Non exhaustible
- Very reliable energy source
- Not expensive to maintain once the dam has been built that is economically attractive than any other option.
- Can increase the plant's production or decrease it whenever there is high or low demand
- Water can be stored, waiting to be used in peak times

DISADVANTAGES

- Building the dam is expensive and time taking
- The dam will change the habitat and landscape upstream, as much more land will be submersed
- The land below the dam is also affected as the flow of water is reduced
- Silt can build up in the dam as the water slows down it does not have enough energy to carry the sand and silt which it was

4. Tidal power

The important outset is to distinguish hydro power from tidal power, tidal power is as result of interaction of the gravitational pull of the moon and, to a lesser extent, the sun, on the seas, schemes that use tidal energy rely on twice- daily tides and the resultant of upstream flows and downstream ebbs in estuaries and the lower reaches of some river, as well as in some cases, tidal movements at seas [1].

5. Wind Energy

Wind Energy - Energy received from the movement of the wind across the earth. This energy is a result of the heating of our oceans, earth, and atmosphere by the sun.
The wind rotates the blade that is attached to a main shaft where a generator is installed. Energy capacity is determined by the size of turbine. Small wind turbines are generally used to power households, farms and ranches in the country. The downside to this technology is the noise that it produces and its relatively expensive installation cost [1].

6. Waves energy

Waves on the oceans are generated by wind passing over stretches of water. Precise mechanisms involved in the interaction between the wind and the surface of the sea are complex. The process can be described as,

- Initially, air flowing over the sea exerts a tangential stress on the water surface, resulting in the formation of the waves.
- Turbulent air flow close to the water surface creating rapid varying shear stress and pressure fluctuations. Here these oscillations are those with existing waves, further wave development.
- Finally, when waves reached a certain size, the wind can exert a stronger force on the up- wind face of the wave, causing additional wave growth.

7. **Geothermal Energy**

The term Geothermal originates from two Geek words 'GEO' and 'THERM'. The Greek word ‘geo’ meant the earth whilst their word for ‘therm’ meant heat from the earth.
Geothermal energy is energy derived from the heat of the earth.
Among the types of renewable energy sources, geothermal is one of the most cost-effective and reliable. Geothermal energy is produced from naturally occurring steam under the Earth's surface thus it’s the only renewable source that independent of solar. Steam is extracted to power a turbine which in turn powers an electric generator. The problem with geothermal energy is the difficulty to find viable land sites. However, the same technology is employed on a smaller scale to power building heaters [1].

Advantages of Geothermal Power

1. Geothermal energy is relatively environmentally friendly. Pollution in the form of fumes is not produced although usually drilling of the earth’s surface takes place. The surrounding environment is not harmed with the exception of the land required for the power plant and transport links.
2. Unlike wind power, geothermal power can be relied on as it provides constant power.
3. The use of conventional polluting fuels such as oil and coal can be reduced if geothermal and other alternative energy forms are used (reducing pollution).
4. Geothermal power can take different forms. For instance, it can be used to produce electricity or the hot water can be used directly to heat homes and businesses.

3.5 Economics

Capital investment in renewable energy theoretically follows the principle of economies of scale, in that average costs will decrease as production volume increases. This is to say that the more renewable energy that is produced, the lower the cost per unit of that energy is. However, most renewable energy projects – particularly solar, wind and geothermal energy, require very high up front capital investments, deterring many investors. Once this initial investment has been made though, materials are generally free. Thus the only costs associated with renewable energy production are maintenance, labor, and regulatory fees.

Aside from fears about global warming, the primary driver behind investment in renewable energy is increasing oil costs. As oil becomes more expensive, renewable energy sources become more attractive. Many people also point to the renewable energy industry as being a young, innovative market, while the fossil fuels industry is very mature.

The industry is particularly suited for developing markets, as production and distribution of fossil fuels can be too expensive in countries without a suitable infrastructure. Furthermore, renewable energy projects in many developing countries have helped lessen poverty, as they provide the energy that businesses need to operate, thus increasing employment.

3.6 Importance

Sustainability– it is evident that eventually our sources of oil and coal will be depleted, at which point we'll need to have already developed an infrastructure of energy production capable of supporting our world, or else we're going to be in serious trouble. The actual time frame for that point is highly debated and has been revised many times over the years.

Energy Security – Producing energy within a nation's own borders decreases dependence on others, increasing security in the event of a cutoff of supply.

Environment – Burning fossil fuels increases the toxic particles in the air, speeding up anthropogenic climate change, or global warming.

3.7 Energy Security

Energy security is a term for an association between national security and the availability of natural resources for energy consumption.

Energy plays an important role in the national security of any given country as a fuel to power the economic engine. Some sectors rely on energy more heavily than others; for example, the Department of Defense relies on petroleum Threats to energy security include the political instability of several energy producing countries, the manipulation of energy supplies, the competition over energy sources, attacks on supply infrastructure, as well as accidents, natural disasters, rising terrorism, and dominant countries reliance to the foreign oil supply.

3.8 Energy Sustainability

Refers to the provision of energy that meets the present demand without compromising the ability of future generations to meet their needs, Technologies that promote sustainable energy include renewable energy sources, such as hydroelectricity, solar energy, wind energy, wave power, geothermal energy, and tidal power, and also technologies designed to improve energy efficiency.

3.9 Energy Accessibility

Electricity is the set of physical phenomena associated with the presence and flow of electric charge. Electricity gives a wide variety of well-known effects, such as lightning, static electricity, electromagnetic induction and the flow of electrical current. In addition, electricity permits the creation and reception of electromagnetic radiation such as radio waves.

3.10 Global Warming and Environmental Pollution

Global warming is when the earth heats up (the temperature rises). It happens when greenhouse gases (carbon dioxide, water vapor, nitrous oxide, and methane) trap heat and light from the sun in the earth's atmosphere, which increases the temperature. This hurts many people, animals, and plants. Many cannot take the change, so they die.

3.10.1 Greenhouse Gasses.

Greenhouse gasses are gasses are in the earth's atmosphere that collects heat and light from the sun. With too many greenhouse gasses in the air, the earth's atmosphere will trap too much heat and the earth will get too hot. As a result people, animals, and plants would die because the heat would be too strong.

3.10.2 Greenhouse Effect.

The greenhouse effect is when the temperature rises because the sun's heat and light is trapped in the earth's atmosphere. This is like when heat is trapped in a car. On a very hot day, the car gets hotter when it is out in the parking lot. This is because the heat and light from the sun can get into the car, by going through the windows, but it can't get back out. This is what the greenhouse effect does to the earth. The heat and light can get through the atmosphere, but it can't get out. As a result, the temperature rises.

Although the greenhouse effect makes the earth able to have people living on it, if there gets to be too many gases, the earth can get unusually warmer, and many plants, animals, and people will die. They would die because there would be less food (plants like corn, wheat, and other vegetables and fruits). This would happen because the plants would not be able to take the heat. This would cause us to have less food to eat, but it would also limit the food that animals have. With less food, like grass, for the animals that we need to survive (like cows) we would even have less food. Gradually, people, plants, and animals would all die of hunger.

3.10.3 Global Warming.

Global warming is affecting many parts of the world. Global warming makes the sea rise, and when the sea rises, the water covers many low land islands. This is a big problem for many of the plants, animals, and people on islands. The water covers the plants and causes some of them to die. When they die, the animals lose a source of food, along with their habitat. Although animals have a better ability to adapt to what happens than plants do, they may die also. When the plants and animals die, people lose two sources of food, plant food and animal food. They may also lose their homes. As a result, they would also have to leave the area or die. This would be called a break in the food chain, or a chain reaction, one thing happening that leads to another and so on.

The oceans are affected by global warming in other ways, as. One thing that is happening is warm water, caused from global warming, is harming algae that animals depend on (A producer is something that makes food for other animals through photosynthesis, like grass.)

Global warming is doing many things to people as well as animals and plants. It is killing algae, but it is also destroying many huge forests. The pollution that causes global warming is linked to acid rain. Acid rain gradually destroys almost everything it touches. Global warming is also causing many more fires that wipe out whole forests. This happens because global warming can make the earth very hot. In forests, some plants and trees leaves can be so dry that they catch on fire.

3.10.4 Causes

Many things cause global warming. One thing that causes global warming is electrical pollution. Electricity causes pollution in many ways, some worse than others. In most cases, fossil fuels are burned to create electricity. Fossil fuels are made of dead plants and animals. Some examples of fossil fuels are oil and petroleum. Many pollutants (chemicals that pollute the air, water, and land) are sent into the air when fossil fuels are burned. Some of these chemicals are called greenhouse gasses.

We use these sources of energy much more than the sources that give off less pollution. Petroleum, one of the sources of energy, is used a lot. It is used for transportation, making electricity, and making many other things. Some other examples of using energy and polluting the air are:

3.10.5 Remedy

There are concrete actions that citizens, businesses and policymakers can take to reduce global warming emissions. Experience has shown that government policies are critical to spurring and enabling global warming solutions and that individual action alone will not solve the problem.

Boosting energy efficiency: The energy used to power, heat, and cool our homes, businesses, and industries is the single largest contributor to global warming. Energy efficiency technologies allow us to use less energy to get the same—or higher—level of production, service, and comfort. This approach has vast potential to save both energy and money, and can be deployed quickly.

Greening transportation: The transportation sector's emissions have increased at a faster rate than any other energy-using sector over the past decade. A variety of solutions are at hand, including improving efficiency (miles per gallon) in all modes of transport, switching to low-carbon fuels, and reducing vehicle miles traveled through smart growth and more efficient mass transportation systems.

Reviewing up renewable: Renewable energy sources such as solar, wind, geothermal and bioenergy are available around the world. Multiple studies have shown that renewable energy has the technical potential to meet the vast majority of our energy needs. Renewable technologies can be deployed quickly, are increasingly cost-effective, and create jobs while reducing pollution.

Phasing out fossil fuel electricity: Dramatically reducing our use of fossil fuels—especially carbon-intensive coal—is essential to tackle climate change. There are many ways to begin this process. Key action steps include: not building any new coal-burning power plants, initiating a phased shutdown of coal plants starting with the oldest and dirtiest, and capturing and storing carbon emissions from power plants. While it may sound like science fiction, the technology exists to store carbon emissions underground. The technology has not been deployed on a large scale or proven to be safe and permanent, but it has been demonstrated in other contexts such as oil and natural gas recovery. Demonstration projects to test the viability and costs of this technology for power plant emissions are worth pursuing.

Managing forests and agriculture: Taken together, tropical deforestation and emissions from agriculture represent nearly 30 percent of the world's heat-trapping emissions. We can fight global warming by reducing emissions from deforestation and forest degradation and by making our food production practices more sustainable.

Exploring nuclear: Because nuclear power results in few global warming emissions, an increased share of nuclear power in the energy mix could help reduce global warming—but nuclear technology poses serious threats to our security. The question remains: can the safety, proliferation, waste disposal, and cost barriers of nuclear power be overcome?

Developing and deploying new low-carbon and zero-carbon technologies: Research into and development of the next generation of low-carbon technologies will be critical to deep mid-century reductions in global emissions. Current research on battery technology, new materials for solar cells, harnessing energy from novel sources like bacteria and algae, and other innovative areas could provide important breakthroughs.

Ensuring sustainable development: The countries of the world—from the most to the least developed—vary dramatically in their contributions to the problem of climate change and in their responsibilities and capacities to confront it. A successful global compact on climate change must include financial assistance from richer countries to poorer countries to help make the transition to low-carbon development pathways and to help adapt to the impacts of climate change.

Adapting to changes already underway: As the Climate Hot Map demonstrates, the impacts of a warming world are already being felt by people around the globe. If climate change continues unchecked, these impacts are almost certain to get worse. From sea level rise to heat waves, from extreme weather to disease outbreaks, each unique challenge requires locally-suitable solutions to prepare for and respond to the impacts of global warming. Unfortunately, those who will be hit hardest and first by the impacts of a changing climate are likely to be the poor and vulnerable, especially those in the least developed countries. Developed countries must take a leadership role in providing financial and technical help for adaptation.

3.10.6 Chemical Pollutants

Some other chemicals that cause air pollution and are bad for the environment and people are:

Ozone- Ozone is produced when other pollution chemicals combine. It is the basic element of smog. It causes many different kinds of health issues dealing with the lungs. It can damage plants and limit sight. It can also cause a lot of property damage.

VOC's (volatile organic compounds, smog formers)- VOC's are let into the air when fuel is burned. This chemical can cause cancer. It can also harm plants.

NOx (nitrogen dioxide)- This chemical forms smog. It is also formed by burning sources of energy, like gas, coal, and oil, and by cars. This chemical causes problems in the respiratory system (including the lungs). It causes acid rain, and it can damage trees. This chemical can eat away buildings and statues.

CO (carbon monoxide)- The source of this chemical is burning sources of energy. It causes blood vessel problems and respiratory failures.

PM-10 (particulate matter)- The source of this chemical is plowing and burning down fields. It can cause death and lung damage. It can make it hard for people to breathe. The smoke, soot, ash, and dust formed by this chemical can make many cities dirty.

Sulfur Dioxide- This chemical is produced by making paper and metals. This chemical can cause permanent lung damage. It can cause acid rain which kills trees and damages building and statues.

Lead- This chemical is in paint, leaded gasoline, smelters, and in lead storage batteries. It can cause many brain and nerve damages and digestive problems.

4. Electricity and Human Development Index

Throughout the past years various sources of energies have been discovered; fuel, biomass, wind, solar, hydro etc and this has led to an increase of development of different countries in terms human and industry. The changes that have taken place due to increase in demand of electricity are described below

4.1 World Energy Demand and Economic Outlook

The energy market expanded substantially in the World Energy Outlook 2000s, demonstrating the commercial and economic viability of the technology and industry. The world appears to be emerging from the worst economic crisis in decades; many counties have made pledge Copenhagen Accord under to reduce on greenhouse gas emissions, through the commitment made by G-20 and APEC to phase out inefficient fossil fuels subsidies. All this is done to secure the reliable and environmentally sustainable energy system.

Due to the updated projection of energy demand, production, trade and investment the world energy consumption increasing from 472 quadrillion Btu in 2006 to 552 quadrillion Btu in 2015 and 678 quadrillion Btu in 2030—a total increase of 44 percent over the projection period. Total world energy use in 2030 is about 2 percent lower than projected in the International Energy Outlook 2008, largely as the result of a slower overall rate of economic growth in this year's

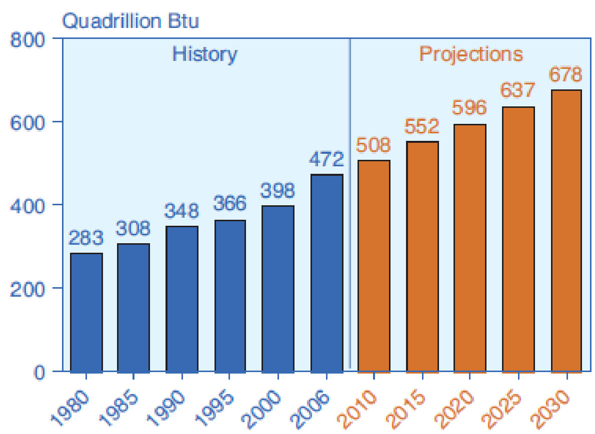

Fig 4.1World Marketed Energy Consumption by country grouping 2006-2030

Sources: History: Energy Information Administration (EIA), International Energy Annual 2006 (June-December 2008), web site www.eia.doe.gov/iea. Projections: EIA, World Energy Projections Plus (2009).

Table 4.1 World Marketed Energy Consumption by country grouping, 2006-2030

Region	Quadrillion Btu						Average Annual percent change,2006-2030
	2006	2010	2015	2020	2025	2030	
OECD	**241.7**	**242.8**	**252.4**	**261.3**	**269.5**	**278.2**	**0.6**
North America	121.3	121.1	125.9	130.3	135.6	141.7	0.6
Europe	81.6	82.2	84.8	87.9	90	91.8	0.5
Asia	38.7	39.5	41.8	43.1	43.9	44.6	0.6
Non OECD	**230.8**	**265.4**	**299.1**	**3334.4**	**367.8**	**400.1**	**2.3**
Europe and Eurasia	50.7s	54	57.6	60.3	62.3	63.3	0.9
Asia	117.6	139.2	163.2	190.3	215.4	239.6	3
Middle East	23.8	27.7	30.3	32.2	34.6	37.7	1.9
Africa	14.5	16.2	17.7	19.1	20.6	21.8	1.7
Central and South America	24.2	28.3	30.3	32.5	35.2	37.7	1.9
Total World	**472.4**	**508.3**	**551.5**	**595.7**	**637.3**	**678.3**	**1.5**

Sources: History: Energy Information Administration (EIA), International Energy Annual 2006 (June-December 2008), web site www.eia.doe.gov/iea. Projections: EIA, World Energy Projections Plus (2009).

4.2 Electricity

World net electricity generation increases by an average of 2.4 percent per year from 2006 to 2030 in the. Electricity is projected to supply an increasing share of the world's total energy demand and is the fastest-growing form of end-use energy worldwide in the mid-term. Since 1990, growth in net electricity generation has outpaced the growth in total energy consumption (2.9 percent per year and 1.9 percent per year, respectively), and the growth in demand for electricity continues to outpace growth in total energy use throughout the projection. World net electricity generation increases by 77 percent, from 18.0 trillion kilowatthours in 2006 to 23.2 trillion kilowatthours in 2015 and 31.8 trillion kilowatthours in 2030. Although the current recession is expected to dampen electricity demand in the near term, the reference case projection does not anticipate that the recession will be prolonged and expects growth in electricity demand to return to trend after 2010. The impact of the recession on electricity consumption is likely to be felt most strongly in the industrial sector, as manufacturing slows as a result of lower demand for manufactured products. Demand in the building sector is less sensitive to changing economic conditions than the industrial sector, because people generally continue to consume electricity for space heating and cooling, cooking, refrigeration, and hot water heating even in a recession.

In general, growth in the OECD countries, where electricity markets are well established and consuming patterns are mature, is slower than in the non-OECD countries, where a large amount of demand goes unmet at present. The International Energy Agency estimates that nearly 32 percent of the population in the developing non-OECD countries (excluding non-OECD Europe and Eurasia) did not have access to electricity in 2005—a total of about 1.6 billion people. Regionally, sub- Saharan Africa fares the worst: more than 75 percent of the population remains without access to power. High projected economic growth rates support strong increases in demand for electricity among the developing regions of the world through the end of the projection period.

Table 4.2 OECD and Non-OECD Net Electricity generation by Energy Source, 2006-2030

Region	Trillion kilowatt hours						Average Annual percent change,2006-2030
	2006	2010	2015	2020	2025	2030	
OECD							
Liquids	0.3	0.3	0.3	0.3	0.3	0.3	-0.4
Natural Gas	2	2.2	2.4	2.7	3	3.1	**1.8**
Coal	3.7	3.9	4	4	4	4.3	0.6
Nuclear	2.2	2.3	2.4	2.4	2.5	2.6	**0.6**
Renewables	1.6	1.6	2.2	2.5	2.8	2.9	2.5
Total OECD	**9.9**	**10.6**	**11.3**	**11.9**	**12.6**	**13.2**	**1.2**
Non-OECD							
Liquids	0.6	0.6	0.6	0.6	0.6	0.6	**0.1**
Natural Gas	1.6	2	2.5	3	3.4	3.7	3.6
Coal	3.7	4.8	5.5	6.4	7.8	9.2	**3.9**
Nuclear	0.4	0.5	0.7	0.9	1.2	1.3	4.8
Renewables	1.8	2.2	2.7	3.2	3.4	3.8	**3.2**
Total Non-OECD	**8**	**10**	**12**	**14.1**	**16.3**	**18.6**	**3.5**
World							
Liquids	0.9	0.9	0.9	0.9	0.9	0.9	-0.1
Natural Gas	3.6	4.2	4.9	5.7	6.4	6.8	2.7
Coal	7.4	8.7	9.5	10.4	11.8	13.6	2.5
Nuclear	2.7	2.8	3	3.4	3.6	3.8	1.5
Renewable	3.4	4.1	4.9	5.7	6.1	6.7	2.9
Total World	**18**	**20.6**	**23.2**	**26**	**28.9**	**31.8**	**2.4**

Source: Energy Information Administration (EIA), International Energy Annual 2006 (June-December 2008),

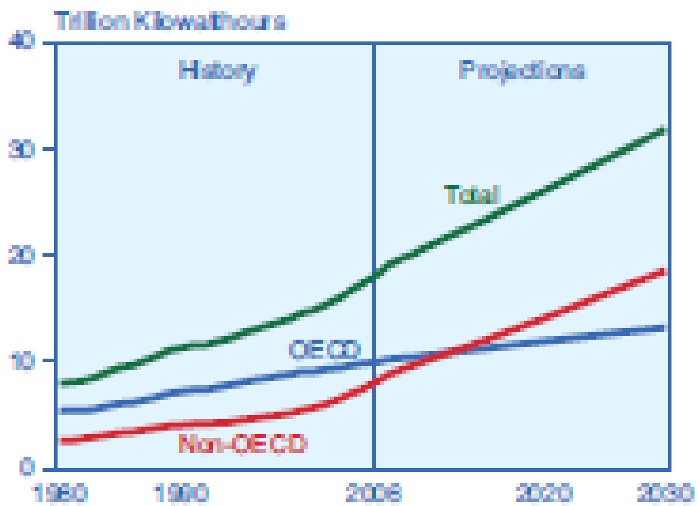

Fig 4.2 OECD and Non-OECD Net Electricity Generation by Energy Source, 2006-2030

Source: Energy Information Administration (EIA), International Energy Annual 2006 (June-December 2008), web site www.eia.doe.gov/iea. Projections: EIA, World Energy Projections Plus (2009)

4.2Electricity and Human Development Index

Progress in human development achieved sustainably is superior to gains made at the cost of future generations

Intergenerational equity and sustainability

When one crisis follows another, it is easy to lose perspective about important long-term consequences of current actions. It is thus important to bear in mind that today's choices can have a large and decisive influence on the choices available for decades in the future. Sustainable human development about understands the links between temporal choices of different generations and about assigning rights to both present and future generations.

Clearly a balance is needed. Enhancing people's capabilities now—especially the capabilities of those who are poor or live with multiple deprivations—is vital as a matter of basic rights and part of the universalism of life claims. Moreover, poverty and misery today have negative consequences for the future. The objective should thus be both intragenerational and intergenerational equity.

Investing in people today requires a prudent balance between debts incurred today and the obligations they impose on future generations.

As the 1994 Human Development Report underscores, “All postponed debts mortgage sustainability, whether economic debts, social debts or ecological debts.” The recent economic crisis has brought to the fore the sustainability of economic debt, public and private, when economies are not growing, while tending to draw attention away from the critical issues of social and ecological debts. On the environmental front, there is already extensive evidence of severe damage to ecosystems from the choices of past and current generations. Poor countries cannot and should not imitate the production and consumption patterns of rich countries. And rich countries must reduce their ecological footprint because from a global perspective their per capita consumption and production are not sustainable. Of particular concern now are the global challenges of climate change and fragile ecosystems. An influential study concluded that “Humanity has already transgressed at least three planetary boundaries,” a point repeated in the 2012 Report of the UN Secretary General’s High Level Panel on Global Sustainability. Few countries are following an ecologically sustainable path now, underscoring the need for technological innovations and shifts in consumption that can facilitate movement towards sustainable

Progress in human development achieved sustainably is superior to gains made at the cost of future generations. Indeed, a proper accounting system for sustainable human development would include both future human development and current achievements. Better ways to monitor environmental

Sustainability is also needed. The 2012 UN Conference on Sustainable Development called for measures that address the connections between present and future sets of choices. Such measures should monitor the accumulation of economic and environmental debt based on the premise that every citizen on the planet, whether alive or not yet born, has an equal right to live a comfortable, fulfilling life. These measures should also highlight planetary boundaries or “tipping points”, recognizing that climate change, for example, already imposes substantial costs, with the brunt of them borne by poor countries and poor communities.

Table 4.3 Very High Human Development

HDI rank		Human Development Index (HDI)	Life expectancy at birth	Mean years of schooling	Expected years of schooling	Gross national income (GNI) per capita	GNI per capita rank minus HDI rank	Nonincome HDI
		Value	(years)	(years)	(years)	(2005 PPP $)		Value
		2012	2012	2010[a]	2011[b]	2012	2012	2012
VERY HIGH HUMAN DEVELOPMENT								
1	Norway	0.955	81.3	12.6	17.5	48,688	4	0.977
2	Australia	0.938	82.0	12.0[c]	19.6[d]	34,340	15	0.978
3	United States	0.937	78.7	13.3	16.8	43,480	6	0.958
4	Netherlands	0.921	80.8	11.6[c]	16.9	37,282	8	0.945
5	Germany	0.920	80.6	12.2	16.4[e]	35,431	10	0.948
6	New Zealand	0.919	80.8	12.5	19.7[d]	24,358	26	0.978
7	Ireland	0.916	80.7	11.6	18.3[d]	28,671	19	0.960
7	Sweden	0.916	81.6	11.7[c]	16.0	36,143	6	0.940
9	Switzerland	0.913	82.5	11.0[c]	15.7	40,527	2	0.926
10	Japan	0.912	83.6	11.6[c]	15.3	32,545	11	0.942
11	Canada	0.911	81.1	12.3	15.1	35,369	5	0.934
12	Korea, Republic of	0.909	80.7	11.6	17.2	28,231	15	0.949
13	Hong Kong, China (SAR)	0.906	83.0	10.0	15.5	45,598	–6	0.907
13	Iceland	0.906	81.9	10.4	18.3[d]	29,176	12	0.943
15	Denmark	0.901	79.0	11.4[c]	16.8	33,518	4	0.924
16	Israel	0.900	81.9	11.9	15.7	26,224	13	0.942
17	Belgium	0.897	80.0	10.9[c]	16.4	33,429	3	0.917
18	Austria	0.895	81.0	10.8	15.3	36,438	–5	0.908
18	Singapore	0.895	81.2	10.1[c]	14.4[f]	52,613	–15	0.880
20	France	0.893	81.7	10.6[c]	16.1	30,277	4	0.919
21	Finland	0.892	80.1	10.3	16.9	32,510	2	0.912
21	Slovenia	0.892	79.5	11.7	16.9	23,999	12	0.936
23	Spain	0.885	81.6	10.4[c]	16.4	25,947	8	0.919
24	Liechtenstein	0.883	79.8	10.3[g]	11.9	84,880[h]	–22	0.832
25	Italy	0.881	82.0	10.1[c]	16.2	26,158	5	0.911
26	Luxembourg	0.875	80.1	10.1	13.5	48,285	–20	0.858
26	United Kingdom	0.875	80.3	9.4	16.4	32,538	–5	0.886
28	Czech Republic	0.873	77.8	12.3	15.3	22,067	10	0.913
29	Greece	0.860	80.0	10.1[c]	16.3	20,511	13	0.899
30	Brunei Darussalam	0.855	78.1	8.6	15.0	45,690	–23	0.832
31	Cyprus	0.848	79.8	9.8	14.9	23,825	4	0.869
32	Malta	0.847	79.8	9.9	15.1	21,184	9	0.876
33	Andorra	0.846	81.1	10.4[i]	11.7	33,918[j]	–15	0.839
33	Estonia	0.846	75.0	12.0	15.8	17,402	13	0.892
35	Slovakia	0.840	75.6	11.6	14.7	19,696	9	0.872
36	Qatar	0.834	78.5	7.3	12.2	87,478[k]	–35	0.761
37	Hungary	0.831	74.6	11.7	15.3	16,088	13	0.874
38	Barbados	0.825	77.0	9.3	16.3	17,308	10	0.859
39	Poland	0.821	76.3	10.0	15.2	17,776	7	0.851
40	Chile	0.819	79.3	9.7	14.7	14,987	13	0.863
41	Lithuania	0.818	72.5	10.9	15.7	16,858	7	0.850
41	United Arab Emirates	0.818	76.7	8.9	12.0	42,716	–31	0.783
43	Portugal	0.816	79.7	7.7	16.0	19,907	0	0.835
44	Latvia	0.814	73.6	11.5[c]	14.8	14,724	10	0.856
45	Argentina	0.811	76.1	9.3	16.1	15,347	7	0.848
46	Seychelles	0.806	73.8	9.4[l]	14.3	22,615	–9	0.808
47	Croatia	0.805	76.8	9.8[c]	14.1	15,419	4	0.837
HIGH HUMAN DEVELOPMENT								
48	Bahrain	0.796	75.2	9.4	13.4[e]	19,154	–3	0.806
49	Bahamas	0.794	75.9	8.5	12.6	27,401	–21	0.777
50	Belarus	0.793	70.6	11.5[l]	14.7	13,385	11	0.830
51	Uruguay	0.792	77.2	8.5[c]	15.5	13,333	11	0.829
52	Montenegro	0.791	74.8	10.5[l]	15.0	10,471	24	0.850
52	Palau	0.791	72.1	12.2	13.7[e]	11,463[m]	18	0.840
54	Kuwait	0.790	74.7	6.1	14.2	52,793	–51	0.730
55	Russian Federation	0.788	69.1	11.7	14.3	14,461	0	0.816
56	Romania	0.786	74.2	10.4	14.5	11,011	16	0.836
57	Bulgaria	0.782	73.6	10.6[c]	14.0	11,474	12	0.826
57	Saudi Arabia	0.782	74.1	7.8	14.3	22,616	–21	0.774
59	Cuba	0.780	79.3	10.2	16.2	5,539[n]	44	0.894
59	Panama	0.780	76.3	9.4	13.2	13,519	1	0.810
61	Mexico	0.775	77.1	8.5	13.7	12,947	4	0.805

Source: Human Development Report 2013 the Rise of the South, Human Progress in a Diverse World

Table 4.4 High Human Development

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		Value	(years)	(years)	(years)	(2005 PPP $)		Value
		2012	2012	2010[a]	2011[b]	2012	2012	2012
62	Costa Rica	0.773	79.4	8.4	13.7	10,863	12	0.816
63	Grenada	0.770	76.1	8.6[e]	15.8	9,257	21	0.827
64	Libya	0.769	75.0	7.3	16.2	13,765	–8	0.791
64	Malaysia	0.769	74.5	9.5	12.6	13,676	–7	0.791
64	Serbia	0.769	74.7	10.2[c]	13.6	9,533	16	0.823
67	Antigua and Barbuda	0.760	72.8	8.9	13.3	13,883	–12	0.776
67	Trinidad and Tobago	0.760	70.3	9.2	11.9	21,941	–28	0.743
69	Kazakhstan	0.754	67.4	10.4	15.3	10,451	8	0.791
70	Albania	0.749	77.1	10.4	11.4	7,822	21	0.807
71	Venezuela, Bolivarian Republic of	0.748	74.6	7.6[c]	14.4	11,475	–2	0.774
72	Dominica	0.745	77.6	7.7[l]	12.7	10,977	–1	0.771
72	Georgia	0.745	73.9	12.1[o]	13.2	5,005	37	0.845
72	Lebanon	0.745	72.8	7.9[l]	13.9	12,364	–5	0.762
72	Saint Kitts and Nevis	0.745	73.3	8.4[e]	12.9	12,460	–5	0.763
76	Iran, Islamic Republic of	0.742	73.2	7.8	14.4	10,695	–1	0.769
77	Peru	0.741	74.2	8.7	13.2	9,306	6	0.780
78	The former Yugoslav Republic of Macedonia	0.740	75.0	8.2[o]	13.4	9,377	2	0.777
78	Ukraine	0.740	68.8	11.3	14.8	6,428	22	0.813
80	Mauritius	0.737	73.5	7.2	13.6	13,300	–17	0.745
81	Bosnia and Herzegovina	0.735	75.8	8.3[l]	13.4	7,713	13	0.787
82	Azerbaijan	0.734	70.9	11.2[l]	11.7	8,153	5	0.780
83	Saint Vincent and the Grenadines	0.733	72.5	8.6[e]	13.3	9,367	–1	0.767
84	Oman	0.731	73.2	5.5[l]	13.5	24,092	–51	0.694
85	Brazil	0.730	73.8	7.2	14.2	10,152	–8	0.755
85	Jamaica	0.730	73.3	9.6	13.1	6,701	14	0.792
87	Armenia	0.729	74.4	10.8	12.2	5,540	16	0.808
88	Saint Lucia	0.725	74.8	8.3[e]	12.7	7,971	1	0.768
89	Ecuador	0.724	75.8	7.6	13.7	7,471	7	0.772
90	Turkey	0.722	74.2	6.5	12.9	13,710	–32	0.720
91	Colombia	0.719	73.9	7.3	13.6	8,711	–6	0.751
92	Sri Lanka	0.715	75.1	9.3[c]	12.7	5,170	18	0.792
93	Algeria	0.713	73.4	7.6	13.6	7,418	4	0.755
94	Tunisia	0.712	74.7	6.5	14.5	8,103	–6	0.746

Source: Human Development Report 2013 the Rise of the South, Human Progress in a Diverse World

Table 4.5 Medium Human Development

HDI rank		Human Development Index (HDI)	Life expectancy at birth	Mean years of schooling	Expected years of schooling	Gross national income (GNI) per capita	GNI per capita rank minus HDI rank	Nonincome HDI
		Value	(years)	(years)	(years)	(2005 PPP $)		Value
		2012	2012	2010[a]	2011[b]	2012	2012	2012
MEDIUM HUMAN DEVELOPMENT								
95	Tonga	0.710	72.5	10.3[c]	13.7	4,153	26	0.807
96	Belize	0.702	76.3	8.0[c]	12.5	5,327	8	0.767
96	Dominican Republic	0.702	73.6	7.2[c]	12.3	8,506	–11	0.726
96	Fiji	0.702	69.4	10.7[c]	13.9	4,087	24	0.794
96	Samoa	0.702	72.7	10.3[l]	13.0	3,928	28	0.800
100	Jordan	0.700	73.5	8.6	12.7	5,272	8	0.766
101	China	0.699	73.7	7.5	11.7	7,945	–11	0.728
102	Turkmenistan	0.698	65.2	9.9[p]	12.6[e]	7,782	–10	0.727
103	Thailand	0.690	74.3	6.6	12.3	7,722	–10	0.715
104	Maldives	0.688	77.1	5.8[c]	12.5	7,478	–9	0.715
105	Suriname	0.684	70.8	7.2[o]	12.4	7,327	–7	0.710
106	Gabon	0.683	63.1	7.5	13.0	12,521	–40	0.668
107	El Salvador	0.680	72.4	7.5	12.0	5,915	–5	0.723
108	Bolivia, Plurinational State of	0.675	66.9	9.2	13.5	4,444	7	0.740
108	Mongolia	0.675	68.8	8.3	14.3	4,245	10	0.746
110	Palestine, State of	0.670	73.0	8.0[l]	13.5	3,359[q]	20	0.761
111	Paraguay	0.669	72.7	7.7	12.1	4,497	4	0.730
112	Egypt	0.662	73.5	6.4	12.1	5,401	–6	0.702
113	Moldova, Republic of	0.660	69.6	9.7	11.8	3,319	19	0.747
114	Philippines	0.654	69.0	8.9[c]	11.7	3,752	11	0.724
114	Uzbekistan	0.654	68.6	10.0[o]	11.6	3,201	19	0.740
116	Syrian Arab Republic	0.648	76.0	5.7[c]	11.7[e]	4,674[r]	–2	0.692
117	Micronesia, Federated States of	0.645	69.2	8.8[p]	11.4[e]	3,352[m]	14	0.719
118	Guyana	0.636	70.2	8.5	10.3	3,387	11	0.703
119	Botswana	0.634	53.0	8.9	11.8	13,102	–55	0.596
120	Honduras	0.632	73.4	6.5	11.4	3,426	8	0.695
121	Indonesia	0.629	69.8	5.8	12.9	4,154	–3	0.672
121	Kiribati	0.629	68.4	7.8[e]	12.0	3,079	13	0.701
121	South Africa	0.629	53.4	8.5[c]	13.1[e]	9,594	–42	0.608
124	Vanuatu	0.626	71.3	6.7[e]	10.6	3,960	–1	0.672
125	Kyrgyzstan	0.622	68.0	9.3	12.6	2,009	24	0.738
125	Tajikistan	0.622	67.8	9.8	11.5	2,119	19	0.731
127	Viet Nam	0.617	75.4	5.5	11.9	2,970	9	0.686
128	Namibia	0.608	62.6	6.2	11.3	5,973	–27	0.611
129	Nicaragua	0.599	74.3	5.8	10.8	2,551	10	0.671
130	Morocco	0.591	72.4	4.4	10.4	4,384	–13	0.608
131	Iraq	0.590	69.6	5.6	10.0	3,557	–4	0.623
132	Cape Verde	0.586	74.3	3.5[e]	12.7	3,609	–6	0.617
133	Guatemala	0.581	71.4	4.1	10.7	4,235	–14	0.596
134	Timor-Leste	0.576	62.9	4.4[s]	11.7	5,446	–29	0.569
135	Ghana	0.558	64.6	7.0	11.4	1,684	22	0.646
136	Equatorial Guinea	0.554	51.4	5.4[o]	7.9	21,715	–97	0.463
136	India	0.554	65.8	4.4	10.7	3,285	–3	0.575
138	Cambodia	0.543	63.6	5.8	10.5	2,095	9	0.597
138	Lao People's Democratic Republic	0.543	67.8	4.6	10.1	2,435	2	0.584
140	Bhutan	0.538	67.6	2.3[s]	12.4	5,246	–31	0.516
141	Swaziland	0.536	48.9	7.1	10.7	5,104	–30	0.515

Source: Human Development Report 2013 the Rise of the South, Human Progress in a Diverse World

Table 4.6 Low human Development

HDI rank	Human Development Index (HDI)	Life expectancy at birth	Mean years of schooling	Expected years of schooling	Gross national income (GNI) per capita	GNI per capita rank minus HDI rank	Nonincome HDI
	Value	(years)	(years)	(years)	(2005 PPP $)		Value
	2012	2012	2010[a]	2011[b]	2012	2012	2012
LOW HUMAN DEVELOPMENT							
142 Congo	0.534	57.8	5.9	10.1	2,934	–5	0.553
143 Solomon Islands	0.530	68.2	4.5[p]	9.3	2,172	1	0.572
144 Sao Tome and Principe	0.525	64.9	4.7[s]	10.8	1,864	7	0.579
145 Kenya	0.519	57.7	7.0	11.1	1,541	15	0.588
146 Bangladesh	0.515	69.2	4.8	8.1	1,785	9	0.567
146 Pakistan	0.515	65.7	4.9	7.3	2,566	–9	0.534
148 Angola	0.508	51.5	4.7[s]	10.2	4,812	–35	0.479
149 Myanmar	0.498	65.7	3.9	9.4	1,817	5	0.537
150 Cameroon	0.495	52.1	5.9	10.9	2,114	–4	0.520
151 Madagascar	0.483	66.9	5.2[p]	10.4	828	28	0.601
152 Tanzania, United Republic of	0.476	58.9	5.1	9.1	1,383	10	0.527
153 Nigeria	0.471	52.3	5.2[s]	9.0	2,102	–6	0.482
154 Senegal	0.470	59.6	4.5	8.2	1,653	4	0.501
155 Mauritania	0.467	58.9	3.7	8.1	2,174	–12	0.473
156 Papua New Guinea	0.466	63.1	3.9	5.8[e]	2,386	–15	0.464
157 Nepal	0.463	69.1	3.2	8.9	1,137	11	0.526
158 Lesotho	0.461	48.7	5.9[c]	9.6	1,879	–8	0.476
159 Togo	0.459	57.5	5.3	10.6	928	16	0.542
160 Yemen	0.458	65.9	2.5	8.7	1,820	–7	0.474
161 Haiti	0.456	62.4	4.9	7.6[e]	1,070	7	0.521
161 Uganda	0.456	54.5	4.7	11.1	1,168	5	0.511
163 Zambia	0.448	49.4	6.7	8.5	1,358	0	0.483
164 Djibouti	0.445	58.3	3.8[o]	5.7	2,350	–22	0.435
165 Gambia	0.439	58.8	2.8	8.7	1,731	–9	0.448
166 Benin	0.436	56.5	3.2	9.4	1,439	–5	0.459
167 Rwanda	0.434	55.7	3.3	10.9	1,147	0	0.476
168 Côte d'Ivoire	0.432	56.0	4.2	6.5	1,593	–9	0.444
169 Comoros	0.429	61.5	2.8[p]	10.2	986	4	0.484
170 Malawi	0.418	54.8	4.2	10.4	774	10	0.492
171 Sudan	0.414	61.8	3.1	4.5	1,848	–19	0.405
172 Zimbabwe	0.397	52.7	7.2	10.1	424[t]	14	0.542
173 Ethiopia	0.396	59.7	2.2[s]	8.7	1,017	–2	0.425
174 Liberia	0.388	57.3	3.9	10.5[e]	480	11	0.502
175 Afghanistan	0.374	49.1	3.1	8.1	1,000	–3	0.393
176 Guinea-Bissau	0.364	48.6	2.3[o]	9.5	1,042	–6	0.373
177 Sierra Leone	0.359	48.1	3.3	7.3[e]	881	0	0.380
178 Burundi	0.355	50.9	2.7	11.3	544	4	0.423
178 Guinea	0.355	54.5	1.6[s]	8.8	941	–4	0.368
180 Central African Republic	0.352	49.1	3.5	6.8	722	1	0.386
181 Eritrea	0.351	62.0	3.4[e]	4.6	531	3	0.418
182 Mali	0.344	51.9	2.0[c]	7.5	853	–4	0.359
183 Burkina Faso	0.343	55.9	1.3[o]	6.9	1,202	–18	0.332
186 Congo, Democratic Republic of the	0.304	48.7	3.5	8.5	319	0	0.404
186 Niger	0.304	55.1	1.4	4.9	701	–4	0.313

Source: Human Development Report 2013 the Rise of the South, Human Progress in a Diverse World

Table 4.7 Other countries or Territories

OTHER COUNTRIES OR TERRITORIES							
Korea, Democratic People's Rep. of	..	69.0	..	..	..	..	..
Marshall Islands	..	72.3	..	11.7	..	..	..
Monaco	..	82.3	..	..	..	..	..
Nauru	..	80.0	..	9.3	..	..	..
San Marino	..	81.9	..	12.5	..	..	..
Somalia	..	51.5	..	2.4	..	..	..
South Sudan	..	..	..	..	..	..	..
Tuvalu	..	67.5	..	10.8	..	..	..
Human Development Index groups							
Very high human development	0.905	80.1	11.5	16.3	33,391	—	0.927
High human development	0.758	73.4	8.8	13.9	11,501	—	0.781
Medium human development	0.640	69.9	6.3	11.4	5,428	—	0.661
Low human development	0.466	59.1	4.2	8.5	1,633	—	0.487
Regions							
Arab States	0.652	71.0	6.0	10.6	8,317	—	0.658
East Asia and the Pacific	0.683	72.7	7.2	11.8	6,874	—	0.712
Europe and Central Asia	0.771	71.5	10.4	13.7	12,243	—	0.801
Latin America and the Caribbean	0.741	74.7	7.8	13.7	10,300	—	0.770
South Asia	0.558	66.2	4.7	10.2	3,343	—	0.577
Sub-Saharan Africa	0.475	54.9	4.7	9.3	2,010	—	0.479
Least developed countries	0.449	59.5	3.7	8.5	1,385	—	0.475
Small island developing states	0.648	69.8	7.3	10.7	5,397	—	0.673
World	**0.694**	**70.1**	**7.5**	**11.6**	**10,184**	**—**	**0.690**

Source: Human Development Report 2013 the Rise of the South, Human Progress in a Diverse World

From the tables above it's observed that much of the news about developing countries in recent decades has been positive, especially their accelerated progress in human development. But what of the future? Can these countries continue to advance human development at the same rapid pace, and can other countries in the South share in the benefits? Yes, with the right policies. These include enhancing equity, enabling voice and participation, confronting environmental pressures and managing demographic change. Policymakers will need to strive for greater policy ambition and to understand the high cost of policy inaction.

5. Electricity Generation

Electricity generation is the process of generating electrical power from other sources of primary energy, by the movement of a loop of wire, or disc of copper between the poles of a magnet

Electricity is most often generated at a power station by electromechanical generators, primarily driven by heat engines fueled by chemical combustion or nuclear fission but also by other means such as the kinetic energy of flowing water and wind. Other energy sources include solar photovoltaic and geothermal power.

5.1 Primary Energy

Primary energy can be non-renewable or renewable.

The concept of primary energy is used in energy statistics in the compilation of energy balances, as well as in the field of energetic. In energetic, a Primary Energy Source (PES) refers to the energy forms required by the energy sector to generate the supply of energy carriers used by human society.

Primary energy sources should not be confused with the energy systems (or conversion processes) through which they are converted into energy carriers

5.1.1 Non Renewable Energy

A non-renewable resource (also known as a finite resource) is a resource that does not renew itself at a sufficient rate for sustainable economic extraction in meaningful human timeframes. An example is carbon-based, organically-derived fuel. The original organic material, with the aid of heat and pressure, becomes a fuel such as oil or gas. Fossil fuels (such as coal, petroleum, and natural gas), and certain aquifers are all examples of non-renewable resources.

Electricity generation from non-renewable resources

Fossil fuels - that's coal, gas and oil - contain lots of energy. When they are burned inside a power station, this energy is transferred by heat and light to water to make lots of steam.

This steam, which is under high pressure, passes through big pipes to a turbine. The high pressure steam makes the turbine rotate.

The turbine is connected to a generator. The generator turns, its energy is transferred by electromagnetic induction to electric current in the circuits it is connected to.

Nuclear power stations also rely on heating water to make steam which turns a turbine which then turns a generator. The difference is, the energy to heat the water in the first place, comes from a nuclear reaction.

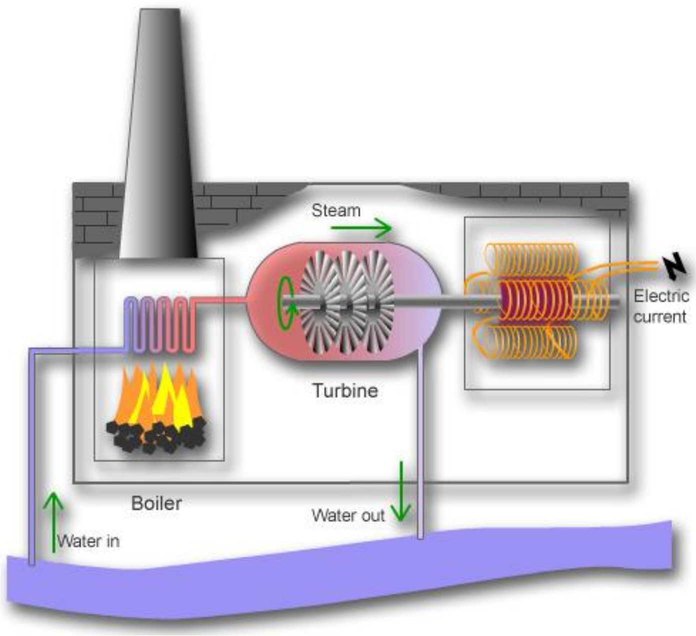


Fig 5.1 Electricity generation from non renewable resource

Sources: http://powerup.ukpowernetworks.co.uk/over-11/electric-journey/non-renewable-energy-sources.aspx

As the generator turns, its energy is transferred by electromagnetic induction to electric current in the circuits it is connected to.

Nuclear power stations also rely on heating water to make steam which turns a turbine which then turns a generator. The difference is, the energy to heat the water in the first place, comes from a nuclear reaction.

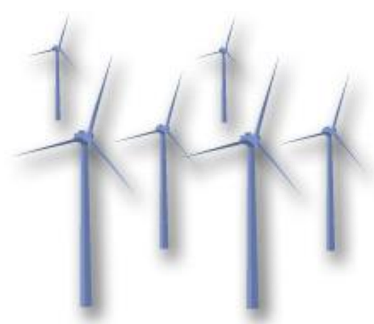
5.1.2 Renewable Energy

Renewable energy sources are ones that won't get used up or run out. There are several types of renewable energy sources but hydroelectric and wind energy currently supply the most energy.

Hydro energy

High dams and reservoirs sometimes have hydro-electric power stations nearby. The water falls under gravity, travelling through huge pipes to get to the power station. In the power station, the energy stored in the falling water is transferred to a turbine. The turbine rotates which in turn, rotates a generator. The generator causes electric current to flow by electromagnetic induction in the wires it is connected to. We often say, 'electricity is generated'.

Wind Energy



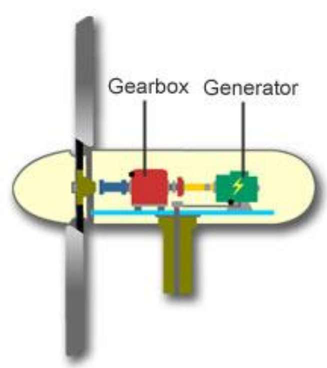


Fig 5.2 Electricity generation from Wind energy

http://powerup.ukpowernetworks.co.uk/over-11/electric-journey/renewable-energy-sources.aspx

A wind turbine contains a rotor connected with some gears to a generator. The generator works in the same way as the ones found in power stations - but are much smaller. The gears make the generators spin fast even when the rotor is spinning slowly.

A collection of wind turbines is called a wind farm. The electrical voltage generated in a wind farm is lower than with fossil fuel, nuclear or hydroelectric power stations.

Other sources of renewable energy which can be used to generate electricity include solar power from the sun, tidal energy from the sea and burning biomass - that's waste plant materials like crops and animal waste.

For renewable electricity generation, decisions include:

- Which energy source or sources to use, e.g. photovoltaic, wind, micro-hydro or a combination of all of these
- Energy requirements, i.e. how much electricity is needed to meet peak and overall demand
- type of electricity storage and/or backup options to use
- Stand-alone or distributed generation system.

Systems must be designed to take account of local conditions (rainfall, wind and town planning) and capacity to meet demand (on-going and peak).

Cost-effectiveness and security of supply should be enhanced by also utilising other energy efficiency measures such as:

- solar water heating
- using energy-efficient appliances
- passive solar space heating
- high levels of insulation

Property type

Wind and hydro systems are generally suitable only for larger rural sites or remote locations. Photovoltaic and small-scale wind generation (if permitted) may be used in urban areas.

Security of supply

An electricity supply must be available at all times, able to meet peak demand and cope with the irregular supply of renewable of renewable energy sources. Batteries for storage of electricity are therefore an integral part of the system.

Alternatively, a diesel generator or connection to the grid is required to ensure a continuous supply of electricity.

5.2 Environmental Effects

All energy sources have some impact on our environment. Fossil fuels — coal, oil, and natural gas — do substantially more harm than renewable energy sources by most measures, including air and water pollution, damage to public health, wildlife and habitat loss, water use, land use, and global warming emissions.

It is still important, however, to understand the environmental impacts associated with producing power from renewable sources such as wind, solar, geothermal, biomass, and hydropower.

The exact type and intensity of environmental impacts varies depending on the specific technology used, the geographic location, and a number of other factors. By understanding the current and potential environmental issues associated with each renewable energy source, we can takes steps to effectively avoid or minimize these impacts as they become a larger portion of our electric supply.

5.3 Climatic Changes

Factors that can shape climate are called climate forcing or forcing mechanisms, These include processes such as variations in solar radiation, variations in the Earth's orbit, mountain-building and continental drift and changes in greenhouse gas concentrations. There are a variety of climate change feedbacks that can either amplify or diminish the initial forcing. Some parts of the climate system, such as the oceans and ice caps, respond slowly in reaction to climate forcing, while others respond more quickly.

Table 5.1 Basic Notion of climatic change

Basic notions	The kind of radiation involved in greenhouse effect	• Sunrays in general • UV radiation bounced off the earth surface • Heat or thermal rays emitted from the sun • Increase of the incoming UV or general solar radiation by the ozone layer depletion
	Distinction of the kinds of radiation and their properties	• Sunrays in general were indicated to be involved in global warming • UV is strong, so very hot radiation coming from the su • No distinction among UV rays, heat rays and high atmospheric temperature
	The kinds of greenhouse gases	• Considering greenhouse gases as air pollutants • Not considering "ground-level ozone" or "gas from fertilizer" as a greenhouse gas • Not considering CO_2 as a greenhouse • Not considering water vapor as a greenhouse gas
	A layer of greenhouse gases, ozone gases or dust trapping heat.	• Greenhouse gases forms a thin around the earth and trap heat inside • Greenhouse effect is that solar rays are trapped by the ozone layer • Heat is trapped under a layer of dust created by pollution • The atmospheric gases make a barrier bouncing back heat from the earth

Source: Fisher, B. (1998). Australian students' appreciation of the greenhouse effect and the ozone hole. Australian Science Journal

Table 5.2 Causes of climatic change

Causes	Environmentally harmful action in general	• Littering • Using environmentally unfavorable products
	Pollution	• Acid rain • Nuclear waste • Air pollution or pollutants in • Pollution in general
	Ozone hole	• The ozone layer depletion in general • Ozone hole lets more solar energy to get into the earth, causing global warming • Ozone hole lets cooler air escape out of the Earth, increasing global average temperature
	Change in solar irradiation	• Increase of solar energy coming into the Earth • The Earth gets closer to the sun • Solar rays hits more areas of the Earth.
Impact	Over estimates of the degree of global warming	• Over estimates of the degree of global warming (e.g., about 7°F increase to date &18.4°F in the • 50 years)
	Depletion of ozone layer	• The greenhouse gases cause ozone layer to deplete • The greenhouse effect causes air pollutants to go up higher and deplete the ozone layer
	General air pollution	• As greenhouse gases are air pollutants, increased greenhouse gases will cause air pollution

Source: Fisher, B. (1998). Australian students' appreciation of the greenhouse effect and the ozone hole.Australian Science Journal

Table 5.3 Resolution to climatic changes

Resolutions	Pro-environmental action in general	• Indicating specific pro-environmental actions, not closely related to global warming (e.g., • Protection of rare species; Reduction of the global nuclear arsenal; Keeping beaches clean, The use of unleaded petrol) • Pro-environmental action in general (e.g., pollute less; put waste in the trashcan; clean the streets)
	Unawareness of the difficulties of CO2 control	• Showing radically positive attitude to the limitation of CO2 emission, implying the unawareness of dependence of modern life on fossil fuel and the huge societal consequences of CO_2 control

Source: Fisher, B. (1998). Australian students' appreciation of the greenhouse effect and the ozone hole. Australian Science Journal

5.4 Past and Future Trend

Energy is a metaphor for the future economic mobility of the world. Deep changes are coming. Energy is mission-essential to the growth, social stability and security of all nations. Oil overdependence and petro-fuel decline offer the world an incentive towards the discovery of renewable energy.

1. Global demand for energy in the near future will outpace supply within twenty-five years unless new sources are found to support global growth.
2. Energy terrorism and theft will become a future weapon of choice, threatening global peace and security.
3. Energy, being linked to all vital services such as health, food, transportation and commerce will be a key driver of future global business.

4. Clean, renewable energy sources such as solar, hydrogen and wind will be essential for future productivity.
5. Oil-dominated energy is politically and economically unsustainable as a reliable source of fuel for the future. Although oil reserves are in supply decline and increasingly costly, oil will continue to play an important role in the 21st century.
6. GDP, growth and productivity will decline if new and cost-effective non-oil energy sources are not found fast to protect future growth and prosperity, and to help rebalance the future of the world.
7. New sources of renewable abundant and cost-effective energy must be fast developed within 20-30 years to manage the population's expectations of enhanced quality of life worldwide.
8. Carbon based pollution, from fossil fuels, will be linked to a growing number of future public health risks.
9. Energy security will be one of the chief concerns in the 21st century leading to global competition, conflict and the collaboration of nations and corporations.
10. Exciting new energy frontiers are emerging such as nanotechnology which will offer promising alternatives to traditional sources of energy in the future.

6. Wind Energy

As we shall see, an understanding of the machine and the system that extract energy from the wind involves the many fields of knowledge, including meteorology, aerodyanamics, electricity and planning, as well structural civil and mechanical engineering.

This chapter begins with description of the atmospheric processes that give rise to wind energy. Wind turbines and their aerodynamics are then described, together with various ways of calculating their power and energy production. This followed by the discussion of the environmental impact and economics of wind energy.

6.1 History

Wind energy was one of the first non animal sources of energy to be exploited by early civilizations. It is thought that wind was first used o propel sailing boats, but the static exploitation of wind energy by means of windmills is believed to have been taking place for about 4000years [1] .

Wind energy has been used for thousands of years for milling grain, pumping water and other mechanical power application. Today, there are several hundred thousand windmills in operation around the world, many of which are used for pumping water. But it is the use of wind energy as pollutant free means of generating electricity on significant scale that is attracting most of the current interest in the subject. Strictly speaking, a windmills used for milling the grain, so modern, windmills tends to be called wind turbines, partly because of their function is similar to the steam and gas turbines, that are used to generate electricity, and partly to distinguish them from the traditional forbears. They are also sometimes referred to as Wind Energy Conversion Systems (WECS) and those used for electricity generation are described as Wind generators or aerogenerators.

Many of the windmills were of the vertical axis type.

Screened windmills. These employ screens or walls around the windmill which are positioned to screen the windmill sails from wind during the backward part of the cycle.

Clapper windmills. These also called because the moveable sails ‘clap’ against stop as rotor turns with the wind (forward), maximizing their air resistance, but align themselves with the wind (like weather vane)when on the part of their cycle in which they are moving into the wind (backward), so reducing the air resistance.

Cyclically pivoting sail wind mills. These are similar to the clapper windmills, but are complex mechanism to achieve progressive changes in sail orientation. The pitch angle of each sail is cyclically adjusted according to its position cycle and to the direction of the wind. This gives a difference in resistances in either side of the windmill's rotation axis, causing it to rotate when exposed to steam.

Differential resistance or cup type windmills. In these windmills, the blades are shaped to offer greater resistances to the wind on the surface compared with other. This results in a difference in wind resistance on either side of the windmill axis, so allowing the wind mill to turn. A modern example of this type of wind driven device is the cu anemometer that is an instrument used to measure wind.

Attempt to generate electricity from wind energy have been made with various degree of success, since the nineteenth century, small wind machines for charging batteries have been manufactured since the 1930s. It is however only since the 1980s that the technology has become sufficiently mature to enable a viable large scale industry to evolve, centred around the manufacturing of the large turbines for electricity generating. The cost of wind turbines fell steadily between the early 1980s and early 2000s.

Wind is now the latest most cost effective methods of electricity generation available in spite of the relatively current low cost of fossil fuels. The technology is contuinally being improved to make it both cheaper and more reliable, so it is expected that wind energy will become ebe economically competitive over the coming decades.

Wind power is also known as one of the fastest growing renewable energy technologies worldwide. That is a total of 31000MW of wind generating capacity that had been installed by the end of 2002, this is about four times the capacity that had been installed by the end of 1997, implying an average growth rate of 40% per annum and past five years average of 28.6%

6.2 Physics

The energy contained in wind is kinetic energy, thus consider a mass of air passing through area A in small time dt is **ρ**Adx,

Where:

ρ is mass/volume,

dx is distance traveled in time **dt,** so **dx = vdt**.

Its kinetic energy, $\frac{1}{2}mv^2$, is therefore $\frac{1}{2}\rho Av^3\,dt$,

The rate of energy passage, or power, is $\frac{1}{2}\rho Av^3$. From the equation we find out that Power in the wind it's proportional to:

- The density of air, the density of air is lower at higher elevations in the mountainous place; but average densities I cold climates may be up 10% higher than the tropical regions.
- The area through which wind is passing; and
- The cube of the wind velocity, wind velocity therefore has a strong influence on power output.

Define velocities: far upstream of a wind machine, call it v_1; at the machine, v; and far downstream, v_2. Following streamlines, the relevant areas are A_1, A and A_2.

The continuity equation is $r_1A_1v_1 = \rho Av = \rho_2A_2v_2$, ……………………………….(1)

or in other words, mass flow rate is a constant. A wind machine can get a force equal to the rate of momentum flow into A_1 minus the rate through A_2 , and power is **Fv**. Momentum flow rate is mass flow rate times velocity, orrAv^2. Thus,

$P = (\rho_1A_1v_1^2 - \rho_2A_2v_2^2)v$……………………………………………………………(2)

Power is also the rate of kinetic energy in minus KE rate out, or

$P= \frac{1}{2}\rho_1A_1v_1^3 - \frac{1}{2}\rho_2A_2v_2^3$ ……………………………………………………………(3)

so we equate these expressions, use the continuity equation to get rid of the **ρ**A terms, then do some algebra, and we find that v is the average of v_1 and v_2, $\mathbf{v = (v_1 + v_2)/2}$. By combining this and the continuity equation with one of the power equations,

$$\mathbf{P= (1/4)\ \rho A\ (v_1^3 - v_2^3 + v_1^2 v_2 - v_1 v_2^2)} \ldots\ldots(4)$$

Nature gives us v_1 and the machine takes energy from the wind, reducing its velocity. At maximum power, $dP/dv_2 = 0$. Do this and it reduces to a quadratic in v_2, from which show $\mathbf{v_2 = v_1/3}$. Insert this above and get

$$P_{max} = \mathbf{(16/27)\ {}^1/_2 \rho A v_1^3} \ldots\ldots(5)$$

The coefficient 16/27 or 0.593 is known as the **Betz coefficient**, after the guy who discovered the derivation. Real coefficients are necessarily much lower, but it is good to have an upper limit to shoot for. The **ρ** is not the ρ_o of still air, but close. It varies with pressure, so using precision like 0.593 is unjustified. I tried to find how **ρ** changes with changes of v_2, but could not find it. The derivation above treats **ρ** as a constant, a good approximation. So the best we can say is that the upper limit of power is in the neighborhood of $(0.6)\ {}^1/_2 \boldsymbol{\rho} A v_1^3$. With a good wind machine, the typical power coefficient is 0.4. Area A is the area swept out. In physics some lab experiments were carried out, the power output of a tiny propeller-generator combination, and found a coefficient of about 0.004. The main problem, was thought of, was due to inefficient generator.

6.3 Technology Development

Most of the Wind Turbines that are currently deployed around the world have three blades, but there are also models with two, four or more at the micro-scale. Rotor diameter is below 20m but most of the commercial small wind turbines have a rotor diameter below 10m. These turbines are mounted typically on 12 to 24m towers.

For the rotor, technology trends are towards advanced blade manufacturing methods based mainly on alternative manufacturing techniques such as injection moulding, compression moulding, and reaction injection moulding. The advantages are shorter fabrication time, lower parts cost, and increased repeatability and uniformity, but tooling costs are higher.

Most of the current Wind Turbines use a synchronous permanent magnet generator based on rare earth permanent magnets as the electromechanical converter for the following reasons:

- Rare earth permanent magnets are now taking over from ferrite magnets: they have superior magnetic properties, and there has been a steady decline in prices; and
- They result in more compact and lighter-weight generators.

An important characteristic to achieve in permanent magnet generators is a reduced generator 'cogging' torque, which enhances low wind speed start-up.

Some manufacturers still continue to use induction generators. However, in the recent past, no turbines of less than 50 kW rated power have used induction generators directly connected to the grid. Currently though, designs utilising induction generators are re-emerging to avoid power electronics in order to achieve reduced cost and improved reliability.

A costly component for grid connected Wind Turbines is the inverter, or DC/AC converter. Most of the inverters used come from the PV market and are being adapted for use with wind turbines, installed downstream of voltage control devices.

Lately, wind-turbine-specific inverters have also started to appear in both single- and three-phase configurations. These can be certified against International Power Quality and EMC (electromagnetic compatibility) standards.

As a general tendency, Wind Turbines are currently designed for low wind speeds, which mean larger rotors, taller towers and precise regulation devices for gust events. Usually the turbine is protected against high winds by yawing or 'furling', in other words the rotor is turned out of the wind passively, by aerodynamic forces. Some alternatives to furling, such as stall control, dynamic brakes, mechanical brakes, and pitch control (both centrifugal and active) have also been developed.

In order to reduce noise emissions, reduced operating and peak rotor speeds are being pursued. Because of this, the typical design tip speed ratio is 5:1.

New standards for Wind Turbines design were published in 2006 for turbines with a rotor area 200m^2 (~ 16m rotor diameter), with slowly increasing use of this standard by the industry.

The industry is diverse and manufacturers vary widely in degree of maturity. Over 300 different models (in various stages of development) exist worldwide, of which 100 are engineered by US manufacturers.

The most recent developments in wind turbines:

- Active pitch controls to maintain energy capture at very high wind speeds.
- Vibration isolators to dampen sound.
- Advanced blade design and manufacturing methods.
- Alternative means of self-protection in extreme winds.
- Adapting a single model to either on-grid or off-grid use.
- Software and wireless display units.
- Inverters integrated into the nacelle (rotor hub).
- Electronics designed to meet stronger safety and durability standards.
- Systems wired for turnkey interconnection.
- Attempts to make Wind Turbines more visually attractive.
- Integrating turbines into existing tower structures, such as utility or lighting poles.

7. System Design

The wind's kinetic energy can be harnessed by a wind turbine. The wind moves the turbine's blades, which transfer energy through a central hub to a generator. The generator converts this mechanical energy into electrical energy that is then delivered to the power grid.

7.1 Wind Data

There are three major wind zones: the polar easterlies, prevailing westerlies, and the trade winds. The wind systems are named based on the direction from which the wind is traveling (the polar easterlies blow from the east; the prevailing westerlies blow from the west). You should notice in the diagram below that none of these global wind systems travels in a straight path. This is due to the Coriolis Effect.

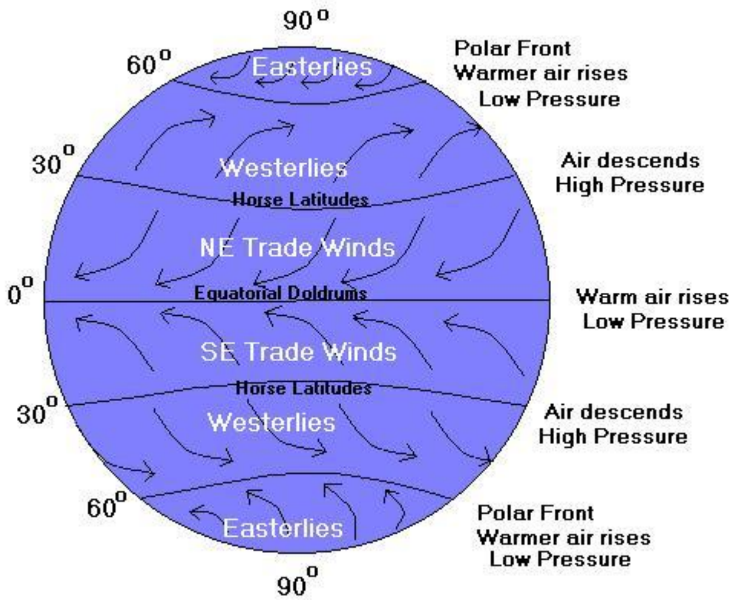


Fig 7.1 Earth's major global wind system

Source: http://facstaff.gpc.edu/~pgore/Earth&Space/GPS/wind.html

From the diagram above, the polar easterlies are located near the poles, starting at 60ºN and S latitude and extending pole ward. The polar easterlies in the northern hemisphere blow from the northeast towards the southwest, while the polar easterlies in the southern hemisphere blow from the southeast towards the northwest. The polar easterly winds begin to blow towards the equator as cold dense air sinks. As the Earth spins on its axis, the Coriolis Effect causes these cold polar winds to be deflected in an easterly direction from each pole.

The prevailing westerlies are located in the northern and southern hemispheres in a zone between 30-60ºN and S latitude. In the northern hemisphere, the prevailing westerlies blow from the southwest towards the northeast and they blow from the northwest towards the southeast in the southern hemisphere. The westerlies are strong, steady winds. In the United States, it is the westerlies that carry most of the weather and storms from the west coast to the east coast. Between the polar easterlies and the prevailing westerlies is a zone of low pressure called the subpolar low. These low pressure areas are associated with cold, stormy weather.

The trade winds are located between 30ºN and 30ºS latitude. The trade winds blow towards the southwest in the northern hemisphere and towards the northwest in the southern hemisphere. Due to the sinking air associated with the trade winds at 30ºN and 30ºS latitude, a high pressure system is established, known as the subtropical high pressure zone (or horse latitudes). The subtropical high pressure zones are associated with little precipitation and weak winds; in fact, many of the world's deserts (e.g. the Sahara) are located in the horse latitudes.

Also associated with the air movement of the trade winds is the intertropical convergence zone (ITCZ). The ITCZ is located where the northern and southern trade winds meet at the equator. This area is also known as the doldrums. The warm, rising air at the ITCZ creates thunderstorms, which is responsible for the high amounts of precipitation that characterize most of the planet's tropical rainforests. To help you remember the wind systems and their locations relative to the high and low pressure zones across the globe,

7.2 System Data

Wind is a clean source of renewable energy that produces no air or water pollution. And since the wind is free, operational costs are nearly zero once a turbine is erected. Mass production and technology advances are making turbines cheaper, and many governments offer tax incentives to spur wind-energy development.

Most wind energy comes from turbines that can be as tall as a 20-story building and have three 200-foot-long (60-meter-long) blades. These contraptions look like giant airplane propellers on a stick. The wind spins the blades, which turn a shaft connected to a generator that produces electricity. Other turbines work the same way, but the turbine is on a vertical axis and the blades look like a giant egg beater.

Some people think wind turbines are ugly and complain about the noise the machines make. The slowly rotating blades can also kill birds and bats, but not nearly as many as cars, power lines, and high-rise buildings do. The wind is also variable: If it's not blowing, there's no electricity generated.

Therefore the load required for present and future industrial, commercial and residential use of electricity has to be put into consideration

7.3 Turbine and Generator

The constructional features of WECS giving emphasis to various components, systems and sub-systems. As off shore installations are getting prominence in the recent years, details of such turbines are also included.

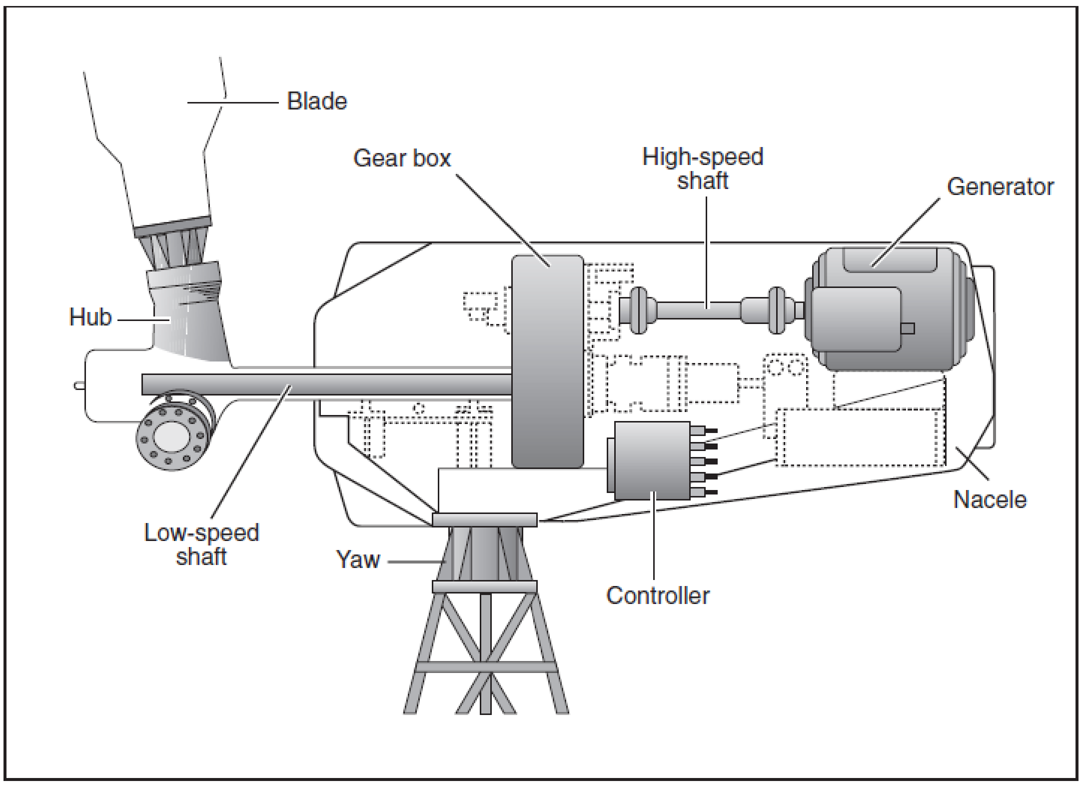


Fig. 7.1.Components of a wind electric generator

Source: Wind Energy Basics, A Guide to Small and Micro Wind Systems. Paul Gipe, Chelsea Green Publishing, 1999.

The Wind Energy Conversion system that is Electricity generation is the most important application of wind energy today. The major components of a commercial wind turbine are:

1. Tower
2. Rotor
3. High speed and low speed shafts
4. Gear box
5. Generator
6. Sensors and yaw drive
7. Power regulation and controlling units
8. Safety systems

7.3.1 Tower

Tower supports the rotor and nacelle of a wind turbine at the desired height. The major types of towers used in modern turbines are lattice tower, tubular steel tower and guyed tower. Schematic views of these towers are shown in Fig. 7.2.

The lattice towers

Lattice towers have several demerits. The major problem is the poor aesthetics as they may be visually unacceptable to some viewers. Similarly, avian activities are more intense around the lattice towers as the birds can conveniently perch on its horizontal bars. This may increase the rate of avian mortality (The major environmental problem with wind energy is avian mortality due to collision with turbines and related structures. Noise emission and the visual impacts on landscapes are the other issues to be tackled.) Lattice towers are not maintenance friendly.

Tubular steel towers

Due to these limitations, most of the recent installations are provided with tubular steel towers. These towers are fabricated by joining tubular sections of 10 to 20 m length. The complete tower can be assembled at the site within 2 or 3 days. The tubular tower, with its circular cross-section, can offer optimum bending resistance in all directions. These towers are aesthetically acceptable and pose less danger to the avian population.

The guyed steel tower for small systems, towers with guyed steel towers are being used. By partially supporting the turbine on guy wires, weight and thus the cost of the tower can be considerably reduced.

Hybrid towers

Due to these problems, hybrid towers are proposed for high capacity systems.

In concrete-tubular hybrid tower, the lower part is made of concrete where as the upper part is with conventional tubular steel structure. One of such design uses prefabricated long and narrow concrete elements for the lower portion. These elements are 10-15 m long, 3-4 m wide and 250-350 mm thick.

Whereas with the guyed wires, size of tubular steel can be reduced. Cost of this tower is slightly higher than other tower options. However, the concept of hybrid towers could reduce the maximum tube diameter required, resolving the transport problem. Similarly, the total mass of the structure could be reduced by 25 per cent.

Lattice Tower Tabular Tower Guyed Tower

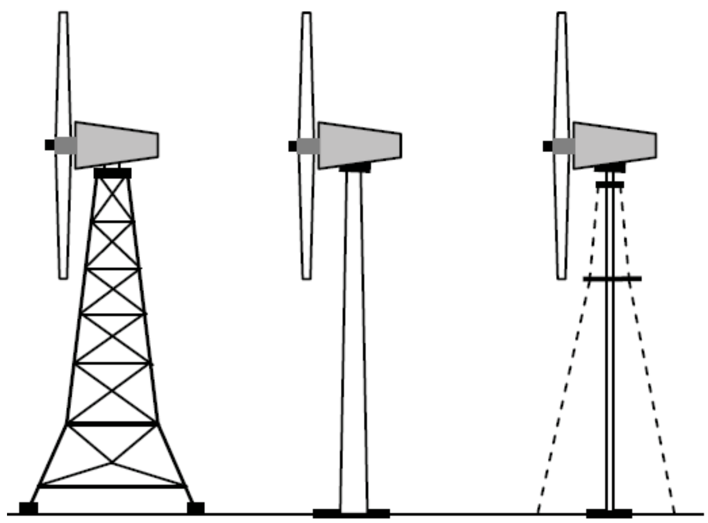


Fig 7.2. Different types of towers

Source: Advanced tower solutions for large wind turbines and extreme tower heights. http://www.mecal.nl, Brughuis FJ

Effect of tower height on the velocity at hub height

Wind velocity increases with height due to wind shear. Hence, the taller the tower, the higher will be the power available to the rotor. Rate at which the available power increases with height depends on the surface roughness of the ground.

The ratio of velocities at two heights Z_R and Z is given by,

$$\frac{V(Z_R)}{V(Z)} = \frac{\ln\left(\frac{Z_R}{Z_0}\right)}{\ln\left(\frac{Z}{Z_0}\right)}$$

Where the Z_0 is the roughness height of the terrain

Apart from the increase in wind velocity, better matching between the wind spectra and the turbine also improves the capacity factor.

Thus, performance of a wind turbine improves with its tower height. However, taller towers cost more. Towers account for around 20 per cent of the total systems cost. At present, cost of every additional 10 m of tower is approximately $15,000.

Cost of wind generated electricity (c) is

$$c = \frac{C_I}{8760\ n}\left(\frac{1}{P_R\ C_F}\right)\left\{1 + m\left[\frac{(1+I)^n - 1}{I\ (1+I)^n}\right]\right\}$$

Where C_I is the capital investment for the system,

n is the expected life,

P_R is the rated power,

C_F is the capacity factor,

m is the maintenance cost and

I is the discounting rate corrected for inflation and escalation. Here, C_I increases with the tower height. However, with increase in height, C_F also improves. Thus, the selection of the optimum tower height is ultimately a trade-in between the cost of the system and its performance.

The optimum tower height for a system is a site specific issue. Wind shear varies from place to place depending on the ground conditions. Apart from the shear, presence of trees or other obstructions in the wind flow path may demand taller towers.

There are some limitations for increasing the tower height. Taller towers are more visible and thus would aggravate the aesthetic issues of wind turbines. The tower height may also have to be restricted due to regulatory limits. The maximum permissible limit may vary from country to country. For example, in United States, this limit is 61.4 m. German regulations exempt a height upto 100 m from obstruction marking. If the turbines happen to be in prominent flight paths, the regulatory authorities may insist for navigation lights on taller towers. Unfortunately, any such markings may make the tower more visible to the public, thus causing visual annoyance. Further, extra heights added to the tower may cause its servicing and maintenance difficult, unless we have specialized lifts to reach the nacelle. Requirement of such devices may not be economically justifiable in many cases. Final decision on the tower height should be made after considering all these factors.

7.3.2 Rotor

Rotor is the most important and prominent part of a wind turbine. The rotor receives the kinetic energy from the wind stream and transforms it into mechanical shaft power. Components of a wind turbine rotor are blades, hub, shaft, bearings and other internals.

Blades of the wind turbine have airfoil, though it is possible to design the rotor with a single blade, balancing of such rotors would be a real engineering challenge. Rotors with single blade run faster and thus create undue vibration and noise. Further, such rotors are not visually acceptable.

Two bladed rotors also suffer from these problems of balancing and visual acceptability. Hence, almost all commercial designs have three bladed rotors. Some of the small wind turbines, used for battery charging, have more number of blades- four, five or even six-as they are designed to be self starting even at low wind speeds.

Size of the rotor depends on the power rating of the turbine. The turbine cost, in terms of $ per rated kW, decreases with the increase in turbine size. Hence, MW sized designs are getting popular in the industry.

Blades are fabricated with a variety of materials ranging from wood to carbon composites. Use of wood and metal are limited to small scale units. Most of the large scale commercial systems are made with multi layered fiberglass blades. Attempts are being made to improve the blade behavior by varying the matrix of materials, reinforcement structures, ply terminations and manufacturing methods.

The traditional blade manufacturing method is open mold, wet lay-up. Some of the manufacturers are making their blades by Vacuum Assisted Resin Transfer Molding (VARTM).

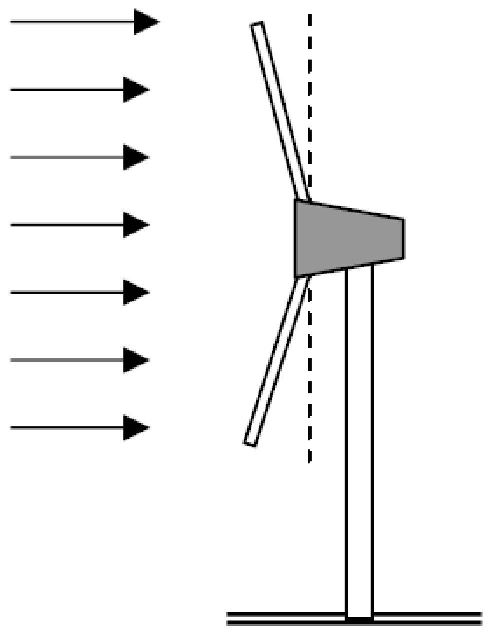


Fig. 7.3 Pre-bending of blades

Source: Advanced tower solutions for large wind turbines and extreme tower heights. http://www.mecal.nl, Brughuis FJ

With the increase in size, carbon-glass hybrid blades are being tried by some manufactures. These blades are expected to show better fatigue characteristics under severe and repetitive loading. The high stiffness characteristic of carbon reduces the possibility of blade bending in high winds and hence, they can be positioned close to the tower. Carbon also improves the edgewise fatigue resistance of the blades which is an advantage for bigger rotors. Weight of the blades can be reduced by 20 per cent by introducing carbon in the design. Usually, weight increases with the cube of the blade length. This can be restricted to an exponent of 2.35 in case of blades with carbon. A lighter blade demands lighter tower, hub and other supporting structures and thus may contribute to the economy of the system. Further, with the introduction of carbon in the design, we can twist couple the blades. Twist coupling improves the turbine performance by better power regulation and quick response to wind gusts. However, carbon-glass hybrid blades are costlier.

Most of the modern wind turbines have up-wind rotors. During wind loading, the blades of these rotors may be pushed towards the tower. This reduces the effective blade length and thus the rotor area. This back bending may also cause fatigue to the blades in due course. To avoid this problem, modern rotors have pre-bend geometries. The pre-bend blades stretch to its total lengths under wind loading, and thus exploit the full potential of the rotor as shown in Fig. 5.4.

Various numerical methods are being followed by the researchers as well as industrial experts to design the rotor and estimate its performance. Some of the popular approaches are:

- The Blade Element Momentum method,
- Vortex Lattice method and
- Reynolds-averaged Navier stokes method.

Computer codes based on these models are also available for the design. All these methods have their inherent merits and demerits. For example, Blade Element Momentum and Vortex Lattice methods are strong in predicting the pre-stalled behavior of the rotor. However, they are inadequate in defining the stall and stall delay performances. Hence, these models may not be accurate in higher wind speeds. Reynolds-averaged Navier stokes method is preferred under these conditions.

Pattern of rotor loading under fluctuating conditions and fatigue properties of materials used should also be considered in the design process. In wind farms, apart from the normal aerodynamic loads, interaction between the turbines may also cause unpredictable and excessive stress on the blades. The design process should consider the conditions of both extreme loading as well as repetitive loading.

In case of extreme loading, the structural stability of the system against a single maximum expected load should be assessed. Usually, the sustainability of the system under an extreme wind load which may occur for 10 minutes, once in every 50 years, is considered.

In the repetitive load analysis, working of the system under a number of adverse conditions which are repeated during the course of operation should be analyzed.

Frequency of occurrence of these conditions may vary and hence, they are weighed on the basis of respective occurrence probability. In both the cases, the system response is assessed as a function of wind speed. There are certain areas of the blade which are more prone to fatigue and failure. For example, near the root section and one-third of the blade near the root are possible failure regions. Another problem is the buckling of the blade at the section of maximum chord, which is further propagated to cause blade failure.

The rotor loading may be analyzed either using parametric methods or empirical methods. In the parametric approach, the response of the systems to a given condition of loads is defined using the statistical models. As this method is based on sound statistical theories, it could be possible to extrapolate the system response under lower or higher frequency levels. Uncertainty levels of the loads can also be included in the analysis. The Weibull distribution is commonly used in the parametric approach.

$$f(u) = \frac{k}{c}\left(\frac{u}{c}\right)^{k-1} \exp\left[-\left(\frac{u}{c}\right)^{k}\right]$$ where ($k>0, u>0, c>1$)

Under the empirical approach, loads on the rotor under a set of simulated conditions are monitored. The system response is observed over a short period-usually 10 minutes-under predefined environmental conditions. This is then extrapolated to the full life time of the turbine.

The major limitation of this method is that the validity of results is limited to the conditions under which the tests are conducted. It may not be practical to include all possible combinations of operating conditions under the simulation process. Hence the parametric analysis is a better tool for estimating the fatigue loads of wind rotors.

Health monitoring of blades while in operation is a possible way to detect and rectify the blade fatigue. If the possibilities of failure are identified at an early stage, remedial measures can be taken, so that the failure zones are not combined and further propagated, causing the total blade collapse. Damage detection methods, like the stress wave monitoring technique, are being effectively used for the health monitoring of blades. A typical system consists of a set of piezo-ceramic patches generating stress waves across the possible failure regions, which are then received by sensors. The signals are further processed to detect the possibilities of fatigue at different blade sections.

The blades of the rotor are attached to hub assembly. The hub assembly consists of hub, bolts, blade bearings, pitch system and internals. Hub is one of the critical components of the rotor requiring high strength qualities. They are subjected to repetitive loading due to the bending moments of the blade root. Due to the typical shape of the hub and high loads expected, it is usually cast in special iron alloys like the spherical graphite (SG) cast iron. Forces acting on the hub make its design a complex process. Three dimensional Finite Element Analysis (FEA) and topological optimization techniques are being effectively used for the optimum design of the hub assembly.

The main shaft of the turbine passes through the main bearings. Roller bearings are commonly used for wind turbines. These bearings can tolerate slight errors in the alignment of the main shaft, thus eliminating the possibility of excessive edge loads. The bearings are lubricated with special quality grease which can withstand adverse climatic conditions. To prevent the risk of water and dirt getting into the bearing, they are sealed, sometimes with labyrinth packing. The main shaft is forged from hardened and tempered steel.

Replacing the bearings of an installed turbine is a very costly work. Hence, to ensure longer life and reliable performance, hybrid ceramic bearings are used with some recent designs. The advantages of ceramic hybrids are that they are stiffer, harder and corrosion free and can sustain adverse operating conditions. These bearings are light in weight and offer smoother performance. Electrically resistant nature of ceramic hybrids eliminates the possibilities of electrical arcing. These bearings are costlier than the standard bearings. However, they can be economical in the long run due to its better performance.

7.3.3 Gear Box

Gear box is an important component in the power trains of a wind turbine. Speed of a typical wind turbine rotor may be 30 to 50r/m in whereas; the optimum speeds of generator may be around 1000 to1500 r/min. Hence, gear trains are to be introduced in the transmission line to manipulate the speed according to the requirement of the generator. An ideal gear system should be designed to work smoothly and quietly-even under adverse climatic and loading conditions-throughout the life span of the turbine. Due to special constraints in the nacelle, the size is also a critica1 factor.

In smaller turbines, the desired speed ratio is achieved by introducing two or three staged gearing system.

However, the ratio between a set of gears are normally restricted to 1:6. Hence, in bigger turbines, integrated gear boxes with a combination of planetary gears and normal gears are used.

A typical gear box may have primary stage planetary gears combined with a secondary two staged spur gears to raise the speed to the desired level. By introducing the planet gears, the gear box size can be considerably reduced. Moreover, planet gears can reliably transfer heavy loads.

Due to its compact design, it is difficult to dissipate the heat generated during the power transmission in planetary gears. A typical 600 kW wind turbine generates waste heat equivalent to 18 kW during its full rate operation. Another problem is the complexity in manufacturing these gears. Beveled gears are less noisy due to the smooth transfer of loads between the adjacent teeth. However, bevel gears cannot be used in planetary gear system.

Bearings for different points of the gear box are selected based on the nature of loads to be transmitted hence, cylindrical roller bearings are recommended. The output shaft has to transmit high speed and low radial loads and hence cage guided cylindrical bearings may be used. Other possible options at this point are self aligning bearings or four point contact ball bearings.

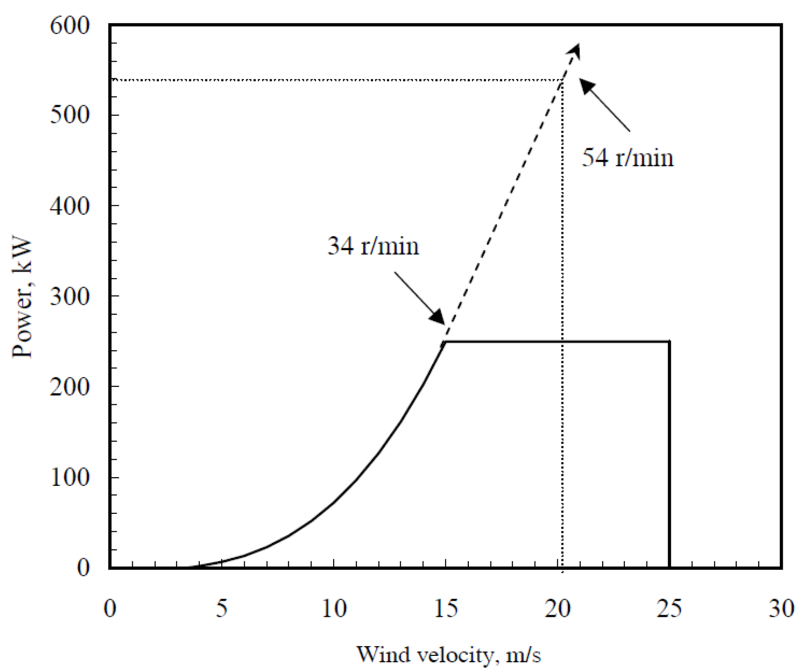


Fig 7.4 Power curve of a typical wind turbine

Source: Advanced tower solutions for large wind turbines and extreme tower heights. http://www.mecal.nl, Brughuis FJ

Gears are designed on the basis of duration and distribution of loads on individual gear teeth. The load duration and distribution pattern (LDD), under a given set of wind conditions, are analysed. This is further extrapolated for the life time of the gears to arrive at the final design. Advanced numerical simulation tools are also being used for characterizing the dynamic response of wind turbine gears and other power trains.

7.3.4 Power Regulation

Power curve of a typical wind turbine is shown in Fig. 6.6. The turbine starts generating power as the wind speeds crosses its cut-in velocity of 3.5 m/s. The power increases with the wind speed upto the rated wind velocity of 15 m/s, at which it generates its rated power of 250 kW. Between the rated velocity and cut-out velocity (25 m/s), the system generates the same rated power of 250 kW, irrespective of the increase in wind velocity.

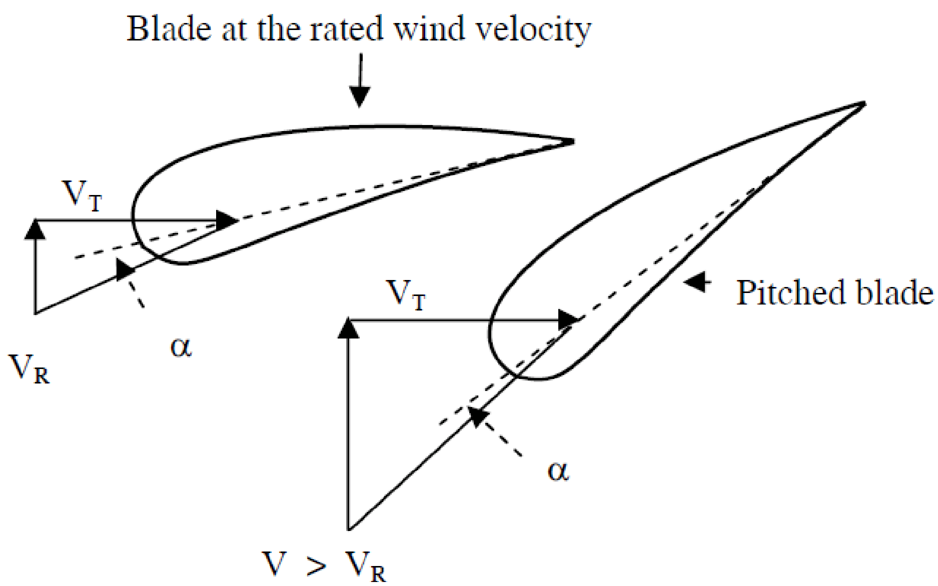


Fig 7.5 Principle of pitch control

Source: Advanced tower solutions for large wind turbines and extreme tower heights. http://www.mecal.nl, Brughuis FJ

Power generated by the turbine is regulated to its rated level between the rated and cut-out wind speeds. If not regulated, the power would have been increased with wind speed as indicated by the dotted lines as in the figure. However, if we want to harness the power at its full capacity even at this high velocity, the turbine has to be designed to accommodate higher levels of power. This means that, the system would require stronger transmission and bigger generator. On the other hand, probability for such high wind velocities is very low in most of the wind regimes. Hence, it is not logical to overdesign the system to accommodate the extra power available for a very short span of time. Speed of the rotor also increases with the wind velocity.

Hence it is vital that the power of the turbine should be regulated at constant level, at velocities higher than the rated wind speed. The common methods to regulate the power are pitch control, stall control, active stall control and yaw control.

Wind turbine blades offer its maximum aerodynamic performance at a given angle of attack. The angle of attack of a given blade profile changes with the wind velocity and rotor speed. Principle of pitch control is illustrated in Fig. 7.5.

Here V_R is the rated wind velocity,

V_T is the velocity of the blades due to its rotation and is the angle of attack.

In a pitch controlled wind turbine, the electronic sensors constantly monitors the variations in power produced by the system. The output power is checked several times in a second.

7.3.5 Safety Brakes

During the periods of extremely high winds, wind turbines should be completely stopped for its safety. Similarly, if the power line fails or the generator is disconnected due to some reason or the other, the wind turbine would rapidly accelerate.

This leads the turbine to run-away condition within a few seconds. Consider wind turbine with rated speed to operate

The system is not designed to tolerate such a high speed and resulting acceleration. Hence, the turbine should essentially be fitted with safety devices, which will break the system and bring it to halt under such conditions.

As the rotor accelerates rapidly, the safety brakes should have rapid reactive response to prevent the run-away condition. Two types of brakes are commonly used with wind turbines. They are aerodynamic brakes and mechanical brakes. In order to ensure the safety, wind turbines usually have two braking systems, one functioning as the primary brake and the other as a backup option which comes in to action if the primary system fails.

Aerodynamic brakes are the primary system in most of the wind turbines. Aerodynamic braking in pitch and stall controlled turbines are different. In pitch and active stall controlled systems, the entire blade is turned 90^0 along its longitudinal axis, there by hindering the driving lift force. Thus the rotor would stop after making a few more rotations. In contrast, it is the tip of the blade which is moved in stalls controlled turbines. Position of the blade tip, relative to the blade, can be changed using a shaft and bearing assembly fixed inside the main body of the blades. During normal operation, the tip is held in position with the blade using hydraulic force.

When the blades are to be stopped, the hydraulic force that keeps the tip in line with the blade is cut-off, thereby allowing the blade tip to move outwards. Driving unit of the blade shaft is then activated which turns the tip through 90^0. This brings the blades to the braking position. Although the blades are not completely stopped by tip braking, the rotor can be brought to a freewheeling speed, which is much lower than its normal operating speed. Once the dangerous situation is over, the blades are brought back to the working position by the hydraulic system. Field experience shows that the aerodynamic braking is quite effective in protecting the turbines.

In addition to the aerodynamic braking, a mechanical brake is also provided with the turbine as a back up system. These brakes are applied to bring the rotor to 'full stop' position in stall controlled turbines. They are also useful to lock the rotor during the turbine maintenance.

Mechanical brakes are friction devices, consisting of brake disc, brake caliper, brake blocks, spring loaded activator and hydraulic control. The brake disc is fixed to the high speed shaft coming from the gear box. Under normal operation, the brake disc and blocks are held apart by hydraulic pressure. When the system is to be braked due to safety reasons, this pressure is released and the brake spring presses the block against the disc. This will bring the system to halt. Being frictional devices operating under extreme loading, the brake blocks are made with special alloys which can tolerate high stress and temperature.

Possibilities of introducing electro-dynamic braking system are also being investigated in large scale fixed speed wind turbines. These brakes, with capacitors and resistors connected to the terminals of rotating induction machine; work on the principle of self excitation. Required braking torque is developed by the current and voltage induced in the machine windings. The braking torque, being a function of rotational speed, can effectively be used for protecting the turbine from reaching the run-away condition

7.3.6 Generator and Converter System

The generator system discussed in this report is a system consisting of a synchronous generator, a diode rectifier, a dc filter and a thyristor inverter. The inverter may have a harmonic filter on the network side if it is necessary to comply with utility demands.

The advantage of a synchronous generator is that it can be connected to a diode or thyristor rectifier. The low losses and the low price of the rectifier make the total cost much lower than that of the induction generator with a self-commutated rectifier. When using a diode rectifier the fundamental of the armature current has almost unity power factor. The induction generator needs higher current rating because of the magnetization current.

The disadvantage is that it is not possible to use the main frequency converter for motor start of the turbine. If the turbine cannot start by itself it is necessary to use auxiliary start equipment. If a very fast torque control is important, then a generator with a self-commutated rectifier allows faster torque response. A normal synchronous generator with a diode rectifier will possibly be able to control the shaft torque up to about 10 Hz, which should be fast enough for most wind turbine generator systems[4] .

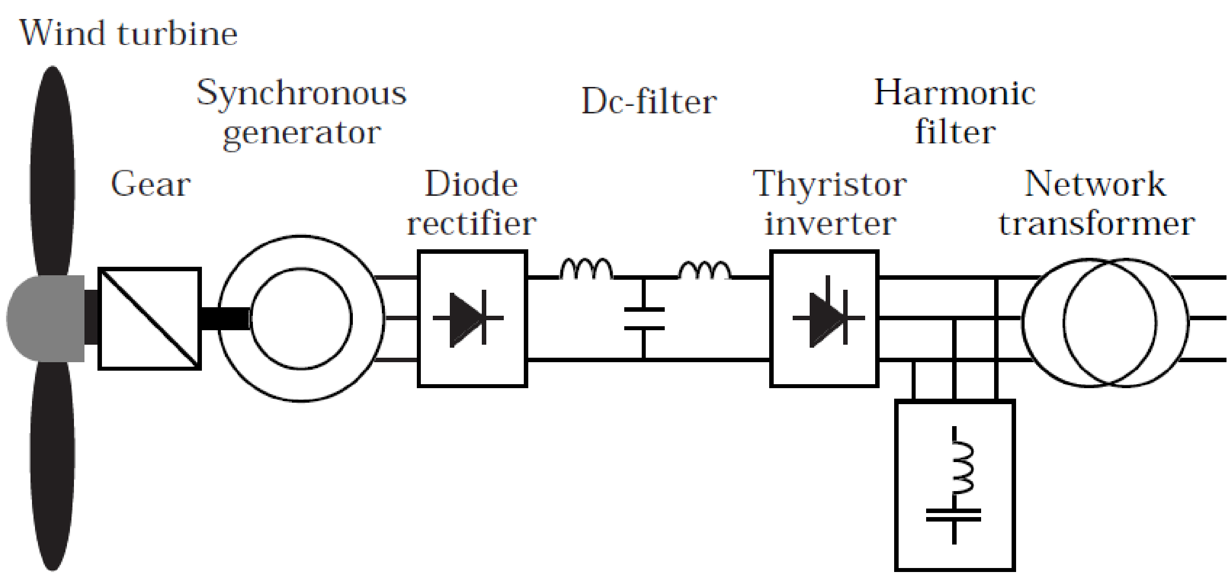


Fig 7.6 Generator and converter system for a wind turbine generator system

Source: MPPT Control Methods in Wind Energy Conversion Systems by Jogendra Singh Thongam and Mohand Ouhrouche.

7.4 Wind Turbine

Wind turbines can rotate about either a horizontal or a vertical axis,

7.4.1 Horizontal Axis

Horizontal-axis wind turbines (HAWT) have the main rotor shaft and electrical generator at the top of a tower, and must be pointed into the wind. Small turbines are pointed by a simple wind vane, while large turbines generally use a wind sensor coupled with a servo motor. Most have a gearbox, which turns the slow rotation of the blades into a quicker rotation that is more suitable to drive an electrical generator.

Since a tower produces turbulence behind it, the turbine is usually positioned upwind of its supporting tower. Turbine blades are made stiff to prevent the blades from being pushed into the tower by high winds. Additionally, the blades are placed a considerable distance in front of the tower and are sometimes tilted forward into the wind a small amount.

Downwind machines have been built, despite the problem of turbulence (mast wake), because they don't need an additional mechanism for keeping them in line with the wind, and because in high winds the blades can be allowed to bend which reduces their swept area and thus their wind resistance. Since cyclical (that is repetitive) turbulence may lead to fatigue failures, most HAWTs are of upwind design.

These turbines used in wind farms for commercial production of electric power are usually three-bladed and pointed into the wind by computer-controlled motors. These have high tip speeds of over 320 km/h (200 mph), high efficiency, and low torque ripple, which contribute to good reliability. The tubular steel towers range from 60 to 90 meters (200 to 300 ft) tall.

7.4.2 Vertical Axis Design

Vertical-axis wind turbines (or VAWTs) have the main rotor shaft arranged vertically. Key advantages of this arrangement are that the turbine does not need to be pointed into the wind to be effective. This is an advantage on sites where the wind direction is highly variable, for example when integrated into buildings. The key disadvantages include the low rotational speed with the consequential higher torque and hence higher cost of the drive train, the inherently lower power coefficient, the 360 degree rotation of the aerofoil within the wind flow during each cycle and hence the highly dynamic loading on the blade, the pulsating torque generated by some rotor designs on the drive train, and the difficulty of modeling the wind flow accurately and hence the challenges of analyzing and designing the rotor prior to fabricating a prototype.

With a vertical axis, the generator and gearbox can be placed near the ground, using a direct drive from the rotor assembly to the ground-based gearbox, hence improving accessibility for maintenance.

7.5 Codes and Standards

The prominent standards are by the American Wind Energy Association (AWEA) and the International Electro Chemical Commission (IECC). The latter is widely used in many parts of Europe and America. Under this standard, the sound power level is measured at10 m height at a referral wind speed of 8 m/s.

As wind power capacity has increased, so has the need for wind power plants to become more active participants in maintaining (rather than passively depending on) the operability and power quality of the electric system. Focusing here primarily on the technical aspects of grid connection, the electrical performance of wind turbines in interaction with the grid is often verified in accordance with international standards for the characteristics of wind turbines, in which methods to assess the impact of one or more wind turbines on power quality are specified (IEC, 2008).

Additionally, an increasing number of electric system operators have implemented technical standards (sometimes called 'grid codes') that wind turbines and/or wind power plants (and other power plants) must meet when connecting to the grid to help prevent equipment or facilities from adversely affecting the electric system during normal operation and contingencies Electric system models and operating experience are used to develop these requirements, which can then typically be met through modifications to wind turbine design or through the addition of auxiliary equipment such as power conditioning devices. In some cases, the unique characteristics of specific generation types are addressed in grid codes, resulting in wind-specific grid codes (e.g., Singh and Singh, 2009).

The requirement for fault ride-through capability was in response to the increasing penetration of wind energy and the significant size of individual wind power plants. Electric systems can typically maintain reliable operation when small individual power plants shut down or is connect from the system for protection purposes in response to fault conditions. When a large amount of wind power capacity disconnects in response to a fault, however, that disconnection can exacerbate the fault conditions.

Electric system planners have therefore increasingly specified that wind power plants must meet minimum fault ride-through standards similar to those required of other large power plants.

7.6 Generation Cost

Projections for the future indicate that the cost would further be reduced to 2.6 cents/kWh by 2020.

There are many factors that affect the economic viability of a wind energy project. They can broadly be grouped as site-specific factors, machine or system parameters, market factors and policy issues. Let us discuss these factors in brief.

7.6.1 Site Specifics

Energy available in wind spectra is proportional to the cube of the wind speed.

This implies that when the speed of the wind at a location doubles, the energy increases by eight times. Hence, the strength of the wind spectra available at the project site is one of the critical factors deciding the cost of wind generated electricity.

When the average velocity increases from, the cost is reduced and by matching the wind profile at the site and the machine requirements is also important in keeping the generation cost to a minimum level.

Cost of land, installation charges and labor wages vary from place to place. Expenditure on foundation depends on the strength of soil profile as well as the extreme loads expected at the site.

In case of grid connected systems, a major concern would be the distance from turbine to existing grid as the cost of developing additional transmission network should also be taken into our calculations.

Extending access from wind farm to existing highways would also contribute to the cost, which may vary from site to site.

As the wind velocity increases with height, systems with taller towers generally produce more power. Towers are one of the costly items in a wind energy system.

The minimum tower height required is determined by the surface roughness of the local area, which is again a site-specific factor. Local climatic conditions also influence the wind energy economics.

Further, presence of corrosive and other harmful substances in the atmosphere reduces life span of the turbine. Frequent maintenance may be necessary due to these factors, which in turn would increase the system's operational and maintenance costs.

7.6.2 Machine

Cost of the wind turbines can be considerably reduced by scaling up the system size. This means that the cost per kW of a 2 MW machine is lower than that of a2 kW unit. Unit cost of wind turbines dropped from $ 2500/kW to $ 750/kW in the last 20 years. This cost reduction is achieved mainly through scaling up the turbine size. Thus, transition of wind energy technology from small units in the earlier days to the MW capacity machines today, has resulted in reducing the cost of wind-generated electricity.

Commercial manufactures reduce the cost of their turbines through typical design improvements. An example is the variable-speed constant-frequency machine.

In these systems, cost of transmission components is reduced by smoothing up the load to be transmitted. At the same time, the aerodynamic efficiency of the rotor is fully exploited due to variable speed option. This will further make the grid integration simpler and efficient.

Economic life span of the turbine influences the cost calculations of wind energy systems. Generally, the life of a wind turbine may vary from 20 to 30 years

However, it must be ensured that the life period taken for our calculations is realistic.

7.6.3 Market

Existing energy market often decides the benefits of wind energy. If the electricity generated from the turbine is completely consumed by the owner, the economic advantage of installing the turbine is decided by the local electricity tariff. However, if the energy produced is in excess to his demand, surplus electricity may be sold to local utility company. Quite often, the rate at which the utility company buys electricity from individual turbine owners is much lower than their local retail-selling price. This is because the company's operational and management expenses as well as the profit are included in the retail tariff.

The rate at which utilities pay for the electricity may depend upon the time of the day at which the power is available.

7.6.4 Incentives and Exemptions

With a view to promote clean and locally available energy sources, several federal and state governments are extending financial support to renewable in terms of exceptions and incentives. These may be in direct or indirect forms. Such supports make the wind energy option more attractive.

Financial supports for the wind energy projects are justifiable. It may appear that the energy market is open and competitive, that is a level playing ground for all the technologies. But it is not truly so. Many conventional energy sources like coal and natural gas enjoy subsidies in hidden forms.

Several developed countries have formulated environmental regulations, which will ultimately come in favor of non-polluting sources like wind. For instance, emission taxes enforced in several countries demands the polluting industries to pay tax, in proportion to the quantity of CO2 and SOX they emit to the atmosphere. This will increase the economic competitiveness of renewable technologies. The nature and level of incentives offered to wind energy varies from region to region.

7.7 Environmental Issues

Environmental and social issues will affect wind energy deployment opportunities.

The energy used and GHG emissions produced in the direct manufacture, transport, installation, operation and decommissioning of wind turbines are small compared to the energy generated and emissions avoided over the lifetime of wind power plants: the GHG emissions intensity of wind energy is estimated to range from 8 to 20 g CO2 /kWh in most instances, whereas energy payback times are between 3.4 to 8.5 months. In addition, managing the variability of wind power output has not been found to significantly degrade the GHG emissions benefits of wind energy. Alongside these benefits, however, wind energy also has the potential to produce some detrimental impacts on the environment and on human activities and well-being.

The construction and operation of wind power plants impacts wildlife through bird and bat collisions and through habitat and ecosystem modifications, with the nature and magnitude of those impacts being site- and species specific. For offshore wind energy, implications for benthic resources, fisheries and marine life must also be considered.

Prominent social concerns include visibility/landscape impacts as well various nuisance effects and possible radar interference.

Research is also underway on the potential impact of wind power plants on the local climate. As wind energy deployment increases and as larger wind power plants are considered, these existing concerns may become more acute and new concerns may arise. Though attempts to measure the relative impacts of various electricity supply technologies suggest that wind energy generally has a comparatively small environmental footprint, impacts do exist. Appropriate planning procedures can reduce the impact of wind energy development on ecosystems and local communities, and techniques for assessing, minimizing and mitigating the remaining concerns could be further improved.

Finally, though community and scientific concerns should be addressed, more proactive planning, and permitting procedures may be required to enable more rapid growth in wind energy utilization.

8. Applications

Over the past years wind energy has used as mean of transport, drying of seeds, due to increasing technology, increasing cost of fuel and policies on Pollution of the environment, the use of wind energy has been changed to generation of electricity since clean and cheap form source of energy.

8.1 History

The wind is a free, clean, and inexhaustible energy source. It has served humankind well for Many centuries by propelling ships and driving wind turbines to grind grain and pump water. Denmark was the first country to use wind for generation of electricity. The Danes were using a 23-m diameter wind turbine in 1890 to generate electricity. By 1910, several hundred units with capacities of 5 to 25 kW were in operation in Denmark (Johnson, 1985). By about 1925, commercial wind-electric plants using two- and three-bladed propellers appeared on the American market. The most common brands were Wind- charger (200 to 1200 W) and Jacobs (1.5 to 3 kW). These were used on farms to charge storage batteries which were then used to operate radios, lights, and small appliances with voltage ratings of 12, 32, or 110 volts. A good selection of 32-VDC appliances was developed by the industry to meet this demand.

Table 8.1The countries with installed capacity until end of 2009

Installed Wind Power Capacity (MW)						
#	Nation	2005	2006	2007	2008	2009
-	European Union	40,722	48,122	56,614	65,255	74,767
1	United States	9,149	11,603	16,819	25,170	35,159
2	Germany	18,428	20,622	22,247	23,903	25,777
3	China	1,266	2,599	5,912	12,210	25,104
4	Spain	10,028	11,630	15,145	16,740	19,149
5	India	4,430	6,270	7,850	9,587	10,925
6	Italy	1,718	2,123	2,726	3,537	4,850
7	France	779	1,589	2,477	3,426	4,410
8	United Kingdom	1,353	1,963	2,389	3,288	4,070
9	Portugal	1,022	1,716	2,130	2,862	3,535
10	Denmark	3,132	3,140	3,129	3,164	3,465
11	Canada	683	1,460	1,846	2,369	3,319
12	Netherlands	1,236	1,571	1,759	2,237	2,229
13	Japan	1,040	1,309	1,528	1,880	2,056
14	Australia	579	817	817	1,494	1,712
15	Sweden	509	571	831	1,067	1,560

Source:http://www.ewea.org/fileadmin/ewea_documents/documents/press_releases/2009/GWEC_Press_Release_-_tables_and_statistics_2008.pdf

8.2 Grid Transfer.

Large-scale use of wind power raises many questions in integration into the existing electric power grid. Wind power is an intermittent energy source which must be used when available. If a large fraction of a system's energy is to come from wind power, provisions must be made to supply load during days with low wind. These provisions might take the form of spinning reserve already allocated in the system, start-up of stand-by power plants, or interconnections to other areas that can take up the load.

Because grid operational strategies are designed for traditional dispatchable energy sources like coal, integrating wind energy into the utility grid can be problematic. Within the power grid, there must be balance between load and generation, economic and policy incentives, cost-effective storage, and robust and distributed control.

Individual turbines are interconnected with a medium voltage (usually 34.5 kV) power collection system and communications network. At a substation, this medium-voltage electrical current is increased in voltage with a transformer for connection to the high voltage electric power transmission system.

A transmission line is required to bring the generated power to (often remote) markets. For an off-shore plant this may require a submarine cable. Construction of a new high-voltage line may be too costly for the wind resource alone, but wind sites may take advantage of lines installed for conventionally fueled generation.

8.3 Hybrid System

A hybrid energy system usually consists of two or more renewable energy sources used together to provide increased system efficiency as well as greater balance in energy supply this can be a combination of wind, solar and diesel generator .

Hybrid energy system is a photovoltaic array coupled with a wind turbine. This would create more output from the wind turbine during the winter, whereas during the summer, the solar panels would produce their peak output. Hybrid energy systems often yield greater economic and environmental returns than wind, solar, geothermalor trigeneration stand-alone systems by themselves.

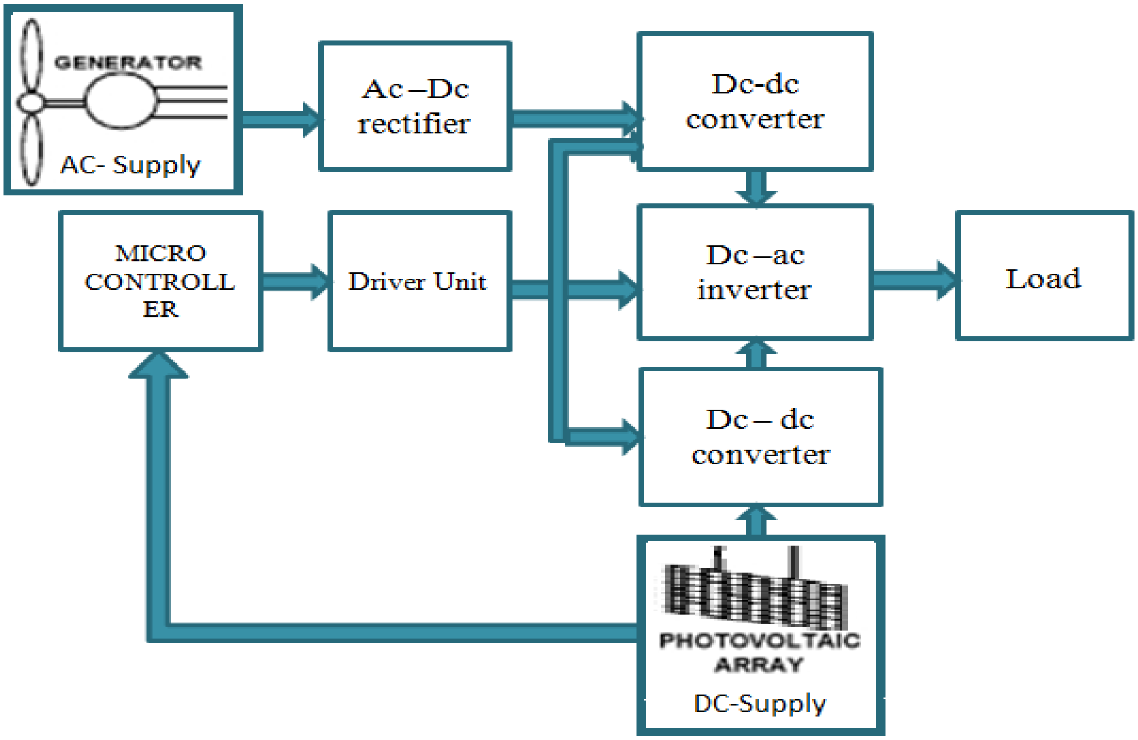


Fig 8.1 Block diagram of a PV/wind hybrid energy system

Source: http://www.slideshare.net/bunny2arya/hybrid-wind-solar-energy-system

9. Leading Countries

The worldwide installed capacity of wind power reached 197 GW by the end of 2010. China (44,733 MW), US (40,180 MW), Germany (27,215 MW) and Spain (20,676 MW) are ahead of India in fifth position.

9.1 America

Wind power is an affordable, efficient and abundant source of domestic electricity. It's pollution-free and cost-competitive with energy from new coal- and gas-fired power plants in many regions. The wind industry has been growing rapidly in recent years. In 2011 alone, 3,464 turbines went up across the United States, and today, American wind generates enough electricity to power more than 11 million homes, creates steady income for investors and landowners, and provides manufacturing, construction and operation jobs for at least 75,000 Americans. A typical 250 MW wind farm (around 100 turbines) will create 1,073 jobs over the lifetime of the project. And by generating additional local and state tax revenues from lease payments, wind farms also have the potential to support other community priorities, such as education, infrastructure, and economic development.

Below is a table showing the capacity of different projects of wind turbines various states in United States of America

Table 9.1 largest wind turbines in United States of America

Project	Capacity (MW)	State
Alta Wind Energy Center	1320	California
Altamont Pass Wind Farm	576	California
Capricorn Ridge Wind Farm	662	Texas
Fowler Ridge Wind Farm	600	Indiana
Horse Hollow Wind Energy Center	736	Texas
Roscoe Wind Farm	781	Texas
San Gorgonio Pass Wind Farm	619	California
Shepherds Flat Wind Farm	845	Oregon
Sweetwater Wind Farm	585	Texas
Tehachapi Pass Wind Farm	705	California
Total	**7429**	

Source: http://en.wikipedia.org/wiki/Wind_power_in_the_United_States

9.2 Germany

Wind and PV production in Germany from daily EEX data shows that around 46 TWh were delivered in 2012 in Germany from wind power and around 28 TWh from solar PV. The [Wind + PV] total 2012 production was around 74 TWh, representing 16.6 % (10.3 % from wind and 6.3 % from PV) of the around 445 TWh delivered by those two renewable energy technologies and by German conventional power plants larger than 100 MW, or 12 % of the preliminary of electricity production in 2012, and below is table showing Installed wind power capacity and generation in recent years.

Table 9.2 Installed wind capacity and generation in Germany

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Installed Capacity (MW)	55	106	174	326	618	1,121	1,549	2,089	2,877	4,435
Generation (GW·h)	71	100	275	600	909	1,500	2,032	2,966	4,489	5,528
% of electricity use	0.01	0.02	0.05	0.1	0.2	0.3	0.4	0.5	0.8	1

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Installed Capacity (MW)	6,097	8,750	11,989	14,604	16,623	18,390	20,579	22,194	23,826	25,703
Generation (GW·h)	7,550	10,509	15,786	18,713	25,509	27,229	30,710	39,713	40,574	38,639
% of electricity use	1.3	1.8	2.7	3.1	4.2	4.4	5	6.4	6.6	6.7

Year	2010	2011	2012
Installed Capacity (MW)	27,191	29,075	31,332
Generation (GW·h)	37,793	46,500	
% of electricity use			

Source: http://en.wikipedia.org/wiki/Wind_power_in_Germany

9.3 China

At the end of 2011, **wind power in the People's Republic of China** accounted for 62 gigawatts (GW) of electricity generating capacity, and China has identified wind power as a key growth component of the country's economy. With its large land mass and long coastline, China has exceptional wind resources It is estimated China has about 2,380 GW of exploitable capacity on land and 200 GW on the sea. China aims to "have 100 gigawatts (GW) of on-grid wind power generating capacity by the end of 2015 and to generate 190 billion kilowatt hours (kWh) of wind power annually". Research from various universities, is has been found out that China could meet all of their electricity demands from wind power through 2030.

By the end of 2008, at least 15 Chinese companies were commercially producing wind turbines and several dozen more were producing components. Turbine sizes of 1.5 MW to 3 MW became common. Leading wind power companies in China were Goldwind, Dongfang Electric, and Sinovel along with most major foreign wind turbine manufacturers. China also increased production of small-scale wind turbines to about 80,000 turbines in 2008. Through all these developments, the Chinese wind industry appeared unaffected by the global financial crisis, according to industry observers.

In 2010, China became the largest wind energy provider worldwide, with the installed wind power capacity reaching 41.8 GW at the end of 2010, but about a quarter of this was not connected to the grid. According to the Global Wind Energy Council, the development of wind energy in China, in terms of scale and rhythm, is absolutely unparalleled in the world. The National People's Congress permanent committee passed a law that requires the Chinese energy companies to purchase all the electricity produced by the renewable energy sector.(citation is incorrect)

As part of the environmental goals included in China's 12th Five Year Plan (2011–2015) targets have been set for non-fossil energy to account for 11.4% of the total energy consumption, and for CO_2 discharge per unit of GDP to reduce by 17%.

9.4 Spain

Spain is the world's fourth biggest producer of wind power, with a year-end installed capacity of 21.6 GW and a share of total electricity consumption of 15.9% in 2011. Belo is a table showing the different areas in Spain with installed wind power capacity

Table 9.3 installed wind power capacity in Spain

Installed wind power capacity (MW)				
Rank	Autonomous Region	2008	2009	2010
1	Castile and León	3,334.04	3,882.72	4,803.82
2	Castile-La Mancha	3,415.61	3,669.61	3,709.19
3	Galicia	3,145.24	3,231.81	3,289.33
4	Andalusia	1,794.99	2,840.07	2,979.33
5	Aragon	1,749.31	1,753.81	1,764.01
6	Valencian Community	710.34	986.99	986.99
7	Navarre	958.77	961.77	968.37
8	Catalonia	420.44	524.54	851.41
9	La Rioja	446.62	446.62	446.62
10	Asturias	304.30	355.95	355.95
11	Basque Country	152.77	152.77	153.25
12	Murcia	152.31	152.31	189.91
13	Canary Islands	134.09	138.34	138.92
14	Cantabria	17.85	17.85	35.30
15	Balearic Islands	3.65	3.65	3.65

Source: http://en.wikipedia.org/wiki/Wind_power_in_Spain

9.5 India

The development of wind power in India began in the 1990s, and has significantly increased in the last few years. Although a relative newcomer to the wind industry compared with Denmark or the United States, India has the fifth largest installed wind power capacity in the world. In 2009-10 India's growth rate was highest among the other top four countries.

As of 31 Jan 2013 the installed capacity of wind power in India was 19564.95MW, It is estimated that 6,000 MW of additional wind power capacity will be installed in India by 2012. Wind power accounts for 8.5% of India's total installed power capacity, and it generates 1.6% of the country's power.

Table 9.4 installed wind capacity in India

States	capacity MW)
Tamil Nadu	7154
Gujarat	3,093
Maharashtra	2976
Karnataka	2113
Rajasthan	2355
Madhya Pradesh	386
Andhra Pradesh	435
Kerala	35.1
Orissa	2
West Bengal	1.1
Other states	3.2

Source: http://en.wikipedia.org/wiki/Wind_power_in_India

10. Participating Countries

10.1 Uganda

The average wind speed in Uganda is about 3 metres per second although speeds of up to 6 m/s have been recorded in flatter areas especially around the Lake Victoria and the Karamoja region as well as hill tops. Pereira da Silva et al. (1999) noted that analysis that have been conducted in the country indicate that there are areas where wind speeds could support power generation.

But on the whole, wind energy has not been widely used, possibly because of the limited awareness on the way wind energy could be used to produce electricity.

10.2 Somalia

Recent developments in the area of wind power generation are very encouraging; particularly in the tropical regions of Asia and Australia and Africa us well. From irrigation projects in the world to power supply in the remote farms in isolated area, wind power generation can play a vital role.

Somalia is a country located in the Horn of Africa. It is bordered by Ethiopia to the west, Djibouti to the northwest, the Gulf of Aden to the north, the Indian Ocean to the east, and Kenya to the southwest. Somalia has the longest coastline on the continent, and its terrain consists mainly of plateaus, plains and highlands. Hot conditions prevail year-round, along with periodic monsoon winds and irregular rainfall.

Wind Speed

The general pattern of wind speed in Somalia is shown in Figure 9.1. Wind speeds are generally between 0.2-8.5 m/s on average. Values do however vary greatly within the year and between seasons. Hargeisa has the highest average value of 17 m/s in July. Low wind speed values (0.2-4 m/s) are observed for most parts of southern Somalia with exception of areas south of lower Juba (8-10 m/s).

Wind speeds are strongest during the south-westerly monsoon (June to August). In the northwest the gradual increase in wind speeds in May and June is notable, From the graph, the winds in the northern parts of the country (Hargeisa, Berbera and Iscusiban) are much stronger than in the south (Mogadishu, Luuq and Kismayo) especially during the Haggai season. On average, the lowest values of wind speed occur in April and October/November in the country, coinciding with the peaks of the two rainy seasons.

10.3 Yemen

The wind energy resource is very large and widely distributed throughout the world as well as in Yemen. Aden possesses a very good potential of wind energy. In this article a number of years data on wind speed in Aden has been studied and presented. A statistical analysis was carried out from which the annual wind speed was found to be 4.5 m/s and most of the time the wind speed is in the range of 3.5–7.5 m/s. The wind speed distributions were represented by Weibull and Rayleigh distributions. It was found that the Rayleigh distribution is suitable to represent the actual probability of wind speed data for Aden. The wind speed data showed that the maximum monthly wind speed occurs in the month of February with the maximum in the month of June. It is concluded that Aden can be explored for wind energy applications.

11.Key Findings

From the data collected the wind energy in key participant countries that is Uganda of wind speed 3-4m/s, Somalia 8-10m/s and Yemen 4-5m/s. we find out that its only Somalia is the only country where wind energy can be efficiently utilized for electricity generation and also Yemen the wind energy projects are under development but for Uganda the wind speed is very slow therefore wind energy will probably be used in farm for wind milling

12.Recommendation and Conclusion

From the data obtained and the research carried out for the various countries it recommended for the countries

Uganda is a country geographically located around the equator with a 3m/s-4m/s speed where by wind energy is less effective for electricity generation but can be used in hilly area for windmills, nevertheless cause good position for solar energy and hydro energy therefore it necessary for electricity to be generated from the solar and can use hybrid system of hydro and solar such that the renewable resources are utilized to maximum efficiently. Though wind is renewable energy everywhere depending on the altitude and latitude so geographic position of country has less effect of wind energy.

Somalia. There is a prospective site of wind electricity generation in many places of Somalia. The wind data at different locations also show similar strength of wind energy. The installation of wind power machines at the coastal and rural areas will be useful for lifting water and for generation of electricity. Wind pumping could play a significant role in the supply of water for irrigation and drinking in the rural areas of developing countries. Since, the prospects of wind energy in Somalia look promising we should engage international and national resources to harness energy from this renewable energy source. It is the appropriate time to expand research and development in the area of wind energy utilization for daily life.
Thus a hybrid energy system is a photovoltaic array coupled with a wind turbine would be more efficient that is wind turbine during the winter, whereas during the summer, the solar panels would produce their peak output. Since it yield greater economic and environmental returns than wind, solar, geothermal or trigeneration stand-alone systems by themselves.

Yemen The wind energy resource is very large and widely distributed throughout the world as well as in Yemen. Aden possesses a very good potential of wind energy.. A statistical analysis was carried out from which the annual wind speed was found to be 4.5 m/s and most of the time the wind speed is in the range of 3.5–7.5 m/s. The wind speed distributions were represented by Weibull and Rayleigh distributions. It was found that the Rayleigh distribution is suitable to represent the actual probability of wind speed data for Aden. The wind speed data showed that the maximum monthly wind speed occurs in the month of

February with the maximum in the month of June. It is concluded that Aden can be explored for wind energy applications.

Abbreviations

EWEA: European Wind Energy Association.

HAWT: Horizontal Axis Wind Turbine

HPS: Hybrid Power Systems

IEC: International Electrotechnical Commission.

ISO: International Organization for Standardization.

IUT: Islamic University of Technology

OECD: Organization Economic Country Development

OIC: Organization of Islamic Cooperation

SCADA: Supervisory Control and Data Acquisition System

UNEP-GEF: United Nations Environment Programme, Division of Global Environment Facility Coordination.

VAWT: Vertical Axis Wind Turbine

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Appendix

Wind and marine energy can power our future, lower greenhouse gas emissions, secure a home-grown supply, and create thousands of jobs -

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Trade association, promoting excellence in energy research, development and deployment.

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