RENEWABLE ENERGY

By Sakshi Gupta

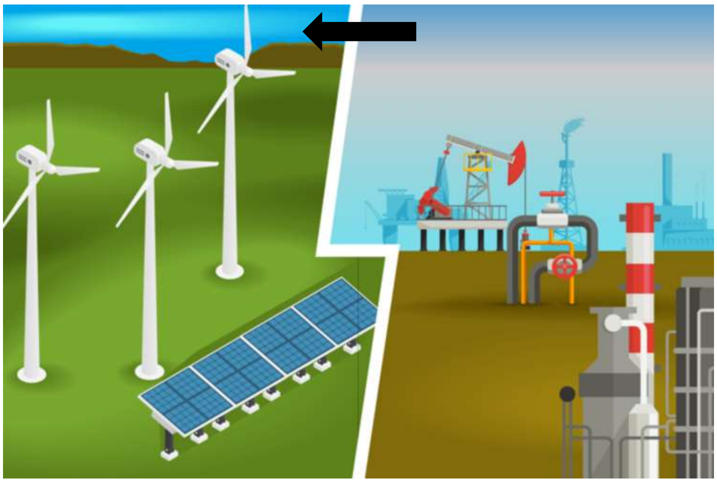
JUNE 29, 2020

CV Raman Nagar, Bangalore, Karnataka

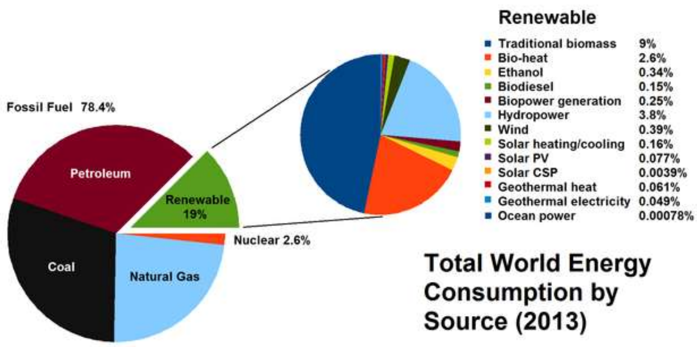
Contents

World Order and Emergence of Renewable Energy

Renewable energy is generated form the sources that don't deplete by generation and are recharged naturally. Commonly used sources are Sun for solar energy, Wind for wind energy or Water for Hydel energy. The most interesting aspect of renewable energy is that the sources are available across the world and never deplete or can be easily recharged. This, thus, helps in eliminating dependency on the sources of energy like petroleum that are concentrated in few countries and are often source of geo-political conflicts.



By middle of last century, world had already stated shifting to non-conventional sources of energy. The surge in industrial demand in developed economies like US and Western Europe were the primary reasons for this growth. By 1980s, the two main non-conventional resources that came into forefront were Hydel and Nuclear. This helped the countries like Germany and France to achieve very high industrial growth and became some of the largest economies without significant increase in their dependency on the petroleum as source of energy. This success led to global push for next couple of decades to find and tap the possible non-conventional sources of energy. The options explored ranged from geo-thermal geysers to tapping energy in tides. By the end of the last century, three additional sources that came into prominence were Sun (solar) and Wind for industrial use in remote locations and biomass as source of energy for rural.

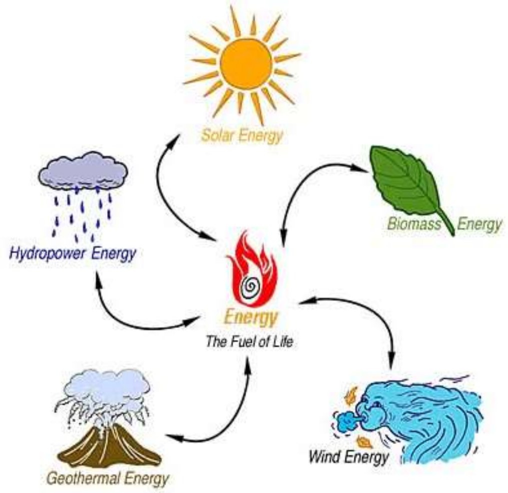


By end of 1st decade of this century, the non-renewable resources like petroleum and coal were severely depleted and their supply concentrated to few selected countries. This made energy generation using these conventional and non-renewable sources extremely expensive. This is also the timeline by when researchers had already made the non-conventional and renewable sources as commercially viable alternatives, thus, planting renewable energy firmly on the global energy grid.

By this time, the Asian economic super-powers of Japan, China and India had either caught up with the west (Europe and North America) on their energy demand or already exceeded it. However, the collective global growth of eastern and western economies came at a severe cost of environment degradation due to excessive use of conventional and non-renewable sources of energy. The big cities like Tokyo, Hong Kong, Mumbai or New Delhi submerged in heavy smog, became a common scenario. This triggered a global demand for mankind to collectively look at green sources of energy and make it a dominant share of energy generation pie. The emergence of green energy as part of UN sustainable development growth and the focus of World economic Forum and World Trade

Organization in using green energy to reduce global carbon footprint accelerated the adoption of renewable energy as commercial viable alternative and key part of the energy mix across most of the national energy grids worldwide.

Commonly tapped sources of renewable energy



The four most used sources of renewable energy are

- Sun (Solar Energy)
- Wind (Wind Energy),
- Water (Hydel Energy)
- Bio-mass (Bio Energy)

Solar Energy

The energy generated by tapping radiant light and heat from the Sun. As per estimates at the start of 1st decade of this century, Sun had potential to provide about 4 times more energy than the requirement of whole world. As per another estimates, the energy Sun provides to earth in just one year is double the possible energy that can be generated through all the fossil fuels on earth. This abundance is the promise that scientists and researchers hope to use to solve world's most of the future energy needs. However, this is easy said than done. Despite decades of scientific research and engineering, current techniques are still just able to leverage 0.1% to 0.25% of the solar energy, making the commercial viability of using solar energy a challenge.

Active (also known as supply side) and Passive (also known as demand side) are the two primary ways through which tapping solar energy is attempted. In Active mechanism, solar energy is tapped using three key techniques

- Photo-voltaic cells
- Solar thermal collectors
- Concentrating solar power

Building roof tops and streetlights with photo-voltaic panels is now-a-days is a common sight. This has become one of the most leveraged technology for electrification of self-dependent remote locations and rural. The common examples of Solar thermal collectors are solar water heaters and solar cookers. Industrial use of solar water heaters for hot water supply is widespread across the world. Concentrating solar power through hyperbola reflectors and using them in generating thermal power was explored in 1st decade of this century across Western Europe and North America. However, off-late this technique s not that popularly exploited with sporadic towers coming up n some parts of Asia and Africa.

In the Passive mechanism, the living and working spaces are designed in a way that they maximize the use of available thermal energy from the Sun and reduce the reliance on electricity. The common techniques used include

- Using construction material that is favorable to solar thermal energy
- Designing spaces that naturally circulate air
- Orienting buildings as per the position of the Sun, to maximize the sunlight availability

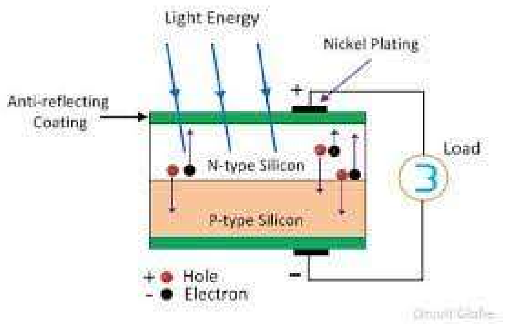
Photo-voltaic cells

The most common active technique is Photo-voltaic cell. The key principal here is a photo-voltaic effect exhibited by certain material. When this material is exposed to sunlight, they absorb sunlight resulting into one of the three following

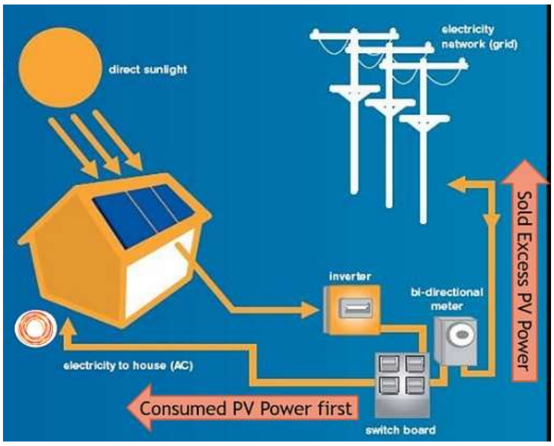
- an electron getting excited to higher energy state
- photon getting absorbed
- thermal gradient due to difference in temperature

All three eventually result in direct current getting generated. Initial experiments for phot-voltaic effects were done with materials like selenium where electron excitation was the key principal. However, soon enough photodiodes came into picture, which slowly and steadily moved the photo-voltaic cells as commercially viable energy sources.

How photodiodes work? Underneath is p-n junction of diodes, where there is already an excited et of electrons available, that need lower threshold energy to get excited and break the balance, thus generating electricity. When sunlight falls upon the photodiode, the electrons present in the valence band absorb energy and jump to the conduction band to become free. Some of these electrons are even accelerated through the rectifying junction due to built-in potential, thus ending into the p-type semiconductor material This generates movement from n-type to p-type by sunlight generates an electrical current.



To commercially tap into solar energy, the photodiodes based phot-voltaic cells are arranged into photo-voltaic systems. Massive panels of these photovoltaic columns are then placed across a large land scape to capture the sunlight falling on the earth. Open grounds, fields, slopes of hills and building roof tops, are most common places where these systems are put. Due to relatively less efficiency of current systems, generally photo-voltaic systems require several large panels. Thus, its needed that these panels are always facing sun, to maximize the exposure. Another aspect to be considered is that photo-voltaic cells, primarily produce direct current, which if transmitted over long distances can result in severe transmission loss. Thus, the integral part of photo-voltaic systems are the battery panels where this direct current can be saved, converted into Alternating Current (AC), and then transmitted to distribution systems for consumptions. In 2017, 1st AC photo-voltaic system was created, however, it's not yet fully commercialized.



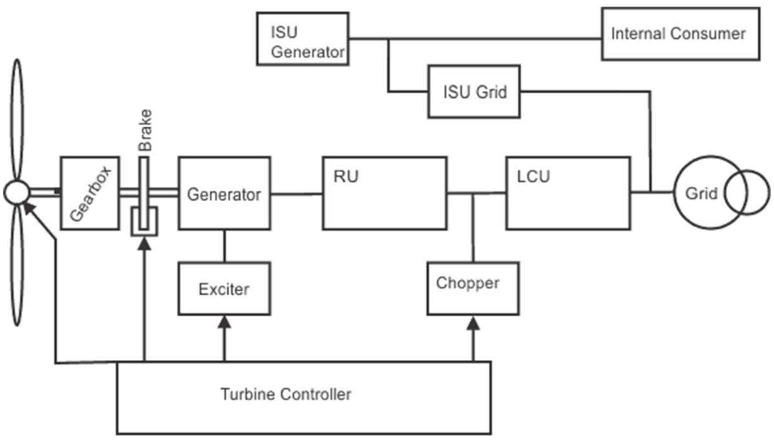
The efficiency of the photovoltaic systems depends on the combination of latitude and climate. These two factors determine the annual energy output of the system. For example, a system with

with 20% efficiency and an area of 1 square meter will produce 200 kWh/year at Standard Test Conditions, but it can produce more when the sun is high in the sky and will produce less in cloudy conditions or when the sun is low in the sky. For example, for a 20% efficiency system, for standard conditions, in the places that get more than 2000 KWhr/ sq m/year of sunlight, expected electrical production per year could e 400 KWH, and same would be just around 300 KWhr if the sunlight falls below 1400 KWhr/sqm/year. Now, same location with higher cloud coverage (above median), can result this 300 KWhr to fall below 175 KWhr.

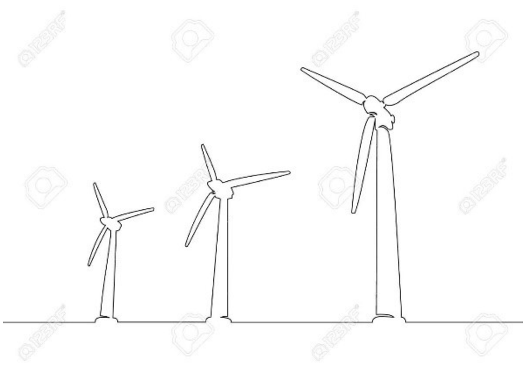
Wind Energy

Wind as a source of energy has been used by mankind for several centuries. From sailors using it for speeding ships to farmers using it to run water mills, wind has been used as source of energy for many civilizations now. And its use in historical and current scenarios can be seen across the globe from China to Argentina. However, use of wind for electricity generation to support power grids is relatively new and more prevalent in current century. The emergence of wind turbines and large wind farms is more of a trend since last decade. Though recent, wind now supplies slightly more than 5% of world electricity. Today, Europe is the leader in use of wind with Denmark leading the pack at 47% penetration. In terms of wind energy capacity, today, China is the leader with about 230 MW capacity installed.

To generate electricity, wind's mechanical energy is captured through large wind turbines who in-turn use it to turn electrical generators and generate power. Today, most turbines use variable speed generators combined with partial- or full-scale power converter between the turbine generator and the collector system, which generally have more desirable properties for grid interconnection and have Low voltage ride through-capabilities. Modern concepts use either doubly fed electric machines with partial-scale converters or squirrel-cage induction generators or synchronous generators (both permanently and electrically excited) with full scale converters.



Generally, these turbines are stacked as huge columns across a large geographical area called wind farm. Inside the far, each turbine is connected to a transmission network. The farm is then connected to either a power grid or a consumption point – generally, an industrial unit or a data center. In a wind farm, individual turbines are interconnected with a medium voltage (often 34.5 kV) power collection system and communications network. In general, a distance of 7D (7 times the rotor diameter of the wind turbine) is set between each turbine in a fully developed wind farm. At a substation, this medium voltage electric current is increased in voltage with a transformer for connection to the high voltage electric power transmission system



Since wind speed is not constant, a wind farm's annual energy production is never as much as the sum of the generator nameplate ratings multiplied by the total hours in a year. The ratio of actual productivity in a year to this theoretical maximum is called the capacity factor. Typical capacity factors are 15–50%; values at the upper end of the range are achieved in favorable sites and are due to wind turbine design improvements. Online data is available for some locations, and the capacity factor can be calculated from the yearly output. The capacity factor depends on several variables - the variability of the wind at the site and the size of the generator relative to the turbine's swept area. A small generator would be cheaper and achieve a higher capacity factor but would produce less electric power (and thus less profit) in high winds. Conversely, a large generator would cost more but generate little extra power and, depending on the type, may stall out at low wind speed. Thus, the capacity factor is often optimal around 40–50%.

The commercial use of wind energy for electricity generation has fair amount of challenges:

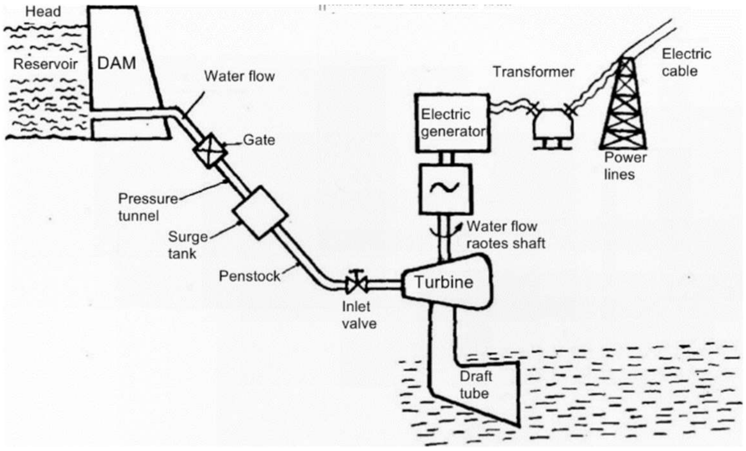
- The on-demand generation of electricity from wind energy is not possible, as it's an intermittent source of energy, as well as, with variable output at any given point of time. Thus, it must be used in conjunction with other more consistent sources of electricity, like hydroelectric power.
- Wind energy also has a management overhead with need to actively deploy power-management techniques including upgraded grids, energy storage, excess capacity, demand management and reduction per power available.
- Transmission losses are also major challenge with wind energy. The wind farms are in very remote locations due to their large size. Either in the middle of the country with no or low population or offshore. This requires very long high-power transmission lines, thus, resulting in large amount of power loss due to transmission.

To handle the inconsistent energy generation and mismatch of demand and supply, Energy storage techniques are applied. The grid energy storage such as compressed air energy storage and thermal energy storage can store energy developed by high-wind periods and release it when needed. The type of storage needed depends on the wind penetration level – low penetration requires daily storage, and high penetration requires both short- and long-term storage. Stored energy increases the economic value of wind energy, since now it can be used to replace higher-cost generation during peak demand periods.

By the second decade of this century, due to technical advancement in turbines and blade material, the overall cost of power generation by wind has considerably reduced. Per some estimates, current cost of 1 KWh is less than 50 cents (Rs 35), which is atleast about 10% lower than cost of 1 KWh from coal. This has spurred the demand of small-scale wind energy power generation systems with capacity around 50 KW. These are often installed on building rooftops in urban centers or in isolated locations and subsidize energy requirement for parking, sensors, night public area illumination and wifi running. In case of large-scale farms, the major customers for them are major utilities around the world. These utilities now offer wind energy as premium offering in their portfolio, which their industrial clients buy to offset their carbon footprint.

Water (Hydel Power)

Kinetic energy of falling or fast-moving water is converted into energy. In ancient times, it was used to turn mills, that would in-turn provide mechanical force to various other machines. By end of 19th century, it was being used to generate electricity as well. Famous Niagara Falls in US is considered to be the 1st commercial hydro-electric station. Through out the 20th century, the word hydro-electricity has been a synonymous to development.



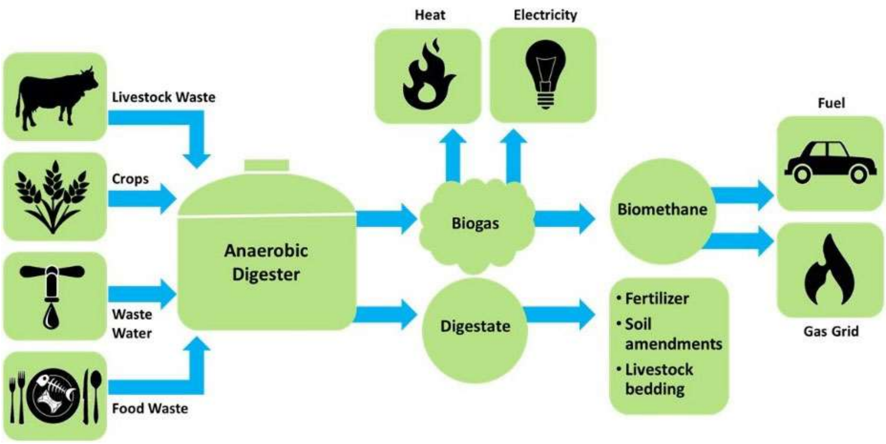
Hydroelectric power plants can include a reservoir (generally created by a dam) to exploit the energy of falling water, or can use the kinetic energy of water as in run-of-the-river hydroelectricity. Dam based power plants provide more dependable generation, as they eliminate the risk of decrease in flow of water with changes in seasons.

Hydroelectric plants can vary in size from small community sized plants (micro hydro) to very large plants supplying power to a whole country. However, large hydro-electric power plants with huge dams, have huge environmental and socio-economic impact. Large dams can ruin river ecosystems, cover large areas of land causing greenhouse gas emissions from underwater rotting vegetation and displace thousands of people and affect their livelihood.

Bio-mass Energy

Biomass is plant or animal material used for energy production. It is typically , wood or forest residues, waste from food crops (wheat straw, bagasse) or or human waste from sewage plants. Off late, horticulture waste, food processing waste, animal farming waste are also being used. Many developed nations like US, and growing economies like India are also specifically growing energy crops.

The largest biomass energy source today is Wood and residues from wood. It is used directly as a fuel or processed into pellet fuel. Biomass also includes plant or animal matter that can be converted into fuel or industrial chemicals. There are numerous types of plants, including corn, switchgrass, miscanthus, hemp, sorghum, sugarcane, and bamboo. The main waste energy feedstocks are wood waste, agricultural waste, municipal solid waste, manufacturing waste, and landfill gas. Sewage sludge is another source of biomass.



Based on the source of biomass, biofuels are classified broadly into two major categories:

- First-generation biofuels are derived from food sources, such as sugarcane and corn starch. Sugars present in this biomass are fermented to produce bioethanol, an alcohol fuel which serve as an additive to gasoline, or in a fuel cell to produce electricity.
- Second-generation biofuels utilize non-food-based biomass sources such as perennial energy crops (low input crops), and agricultural/municipal waste. There is huge potential for second generation bio-fuels but the resources are currently under-utilized.

Biomass conversion could use any of these techniques:

- Thermal conversion processes use heat as the dominant mechanism to upgrade biomass into a better and more practical fuel.
- A range of chemical processes may be used to convert biomass into other forms, such as to produce a fuel that is more practical to store, transport and use, or to exploit some property of the process itself.
- As biomass is a natural material, many highly efficient biochemical processes have developed in nature to break down the molecules of which biomass is composed, and many of these biochemical conversion processes can be harnessed. In most cases, microorganisms are used to perform the conversion process
- Biomass can be directly converted to electrical energy via electrochemical oxidation of the material. This can be performed directly in a direct carbon fuel cell, direct liquid fuel cells such as direct ethanol fuel cell, and a microbial fuel cell

Cofiring with biomass has increased in coal power plants, because it makes it possible to release less CO2 without the cost associated with building new infrastructure. Co-firing is not without issues however, often an upgrade of the biomass is most beneficial. Upgrading to higher grade fuels can be achieved by different methods, broadly classified as thermal, chemical, or biochemical

Renewable Energy as essential ingredient of Energy Management

The objectives of Energy Management are to minimize the cost of energy, increase its utilization and minimize the impact on the environment. Renewable Energy is an essential part to achieve all these three objectives.

Cost of energy: With increasing cost of fossil fuels and huge capital investment layout needed to supply energy to match the demand, Renewable energy is a definite game changer. Not only the sources are cheap or free, even the technology needed to harness renewable energy and use it for human consumption has considerably gone down. In several contexts, using renewable energy to meet demand has becoming way cost effective. A typical strategy today is to replace about 15% of energy demand with renewable energy to optimally offset the cost of the energy

Increase its utilization: Most of the time when human energy demand is to be met, it has to be converted into electricity or heat, and then transmitted form conversion point to consumption point. However, there are several use cases of human consumption where passive energy consumption techniques if applied can result into reducing the demand itself, and increasing the utilization of energy from the source itself. Passive building designs to maximize use of solar and wind energy, and thus, increasing the utilization of available sunlight and wind. Solar water heaters and solar cookers use din industrial application are additional such examples of maximizing the use of available sunlight.

Minimizing the impact to the environment: Last but the most important contribution of renewable energy to energy management objectives. Renewable Energy is key to human survival and economic development in developing countries. On one side economies are impacted by huge cost of fuel prizes, on the other side fossil fuel exploration threatens forests and oceans alike, and thus, severely impact climate change. The increased use of renewable energy reduces the threat of air, water and land pollution. It also helps in re-evaluating the designs in a way that increases the direct utilization of natural resources, thus, reducing the overall carbon foot print.

Renewable energy – key policies and organizations

Rural industrialization using renewable energy

With more than 70% of world still below poverty, and most of the poverty concentrated to rural areas, any sustainable development goal requires that these rural areas have means to develop. Various studies conducted from 2011 to 2015 across developing countries in Asia and Africa, have indicated that the key difference between successful interventions for rural sustained growth and failed ones is the availability of electricity. This study has spawned most of the governments worldwide to target for 100% rural electrification, but most of these incentives are either unable to fund themselves or considerably delayed. For these initiatives of rural electrification, the game changer is renewable energy. Realizing this, 2018 onwards, several countries have now started implementing solar and wind based small scale energy generation systems to support residential and small-scale industrial requirements of rural population. On one side, this has taken away huge capital investment for transmission lines, and the transmission losses, on the other side it has avoided further loading already overloaded power grids.

MNRE, India

The Ministry of New and Renewable Energy (MNRE) is a ministry of the Government of India that is mainly responsible for research and development, intellectual property protection, and international cooperation, promotion, and coordination in renewable energy sources such as wind power, small hydro, biogas, and solar power. The broad aim of the ministry is to develop and deploy new and renewable energy for supplementing the energy requirements of India

The Mission of the Ministry is to ensure

1. Energy Security: Lesser dependence on oil imports through development and deployment of alternative fuels (hydrogen, bio-fuels and synthetic fuels) and their applications to contribute towards bridging the gap between domestic oil supply and demand;
2. Increase in the share of clean power: Renewable (bio, wind, hydro, solar, geothermal & tidal) electricity to supplement fossil fuel based electricity generation;
3. Energy Availability and Access: Supplement energy needs of cooking, heating, motive power and captive generation in rural, urban, industrial and commercial sectors;
4. Energy Affordability: Cost-competitive, convenient, safe, and reliable new and renewable energy supply options; and
5. Energy Equity: Per-capita energy consumption at par with the global average level by 2050, through a sustainable and diverse fuel- mix

Top 10 Government of India initiatives

1. Jawaharlal Nehru National Solar Mission (JNNSM) –
   The National Solar Mission was launched on 11 January 2010. The Mission has set the ambitious target of deploying 20,000 MW of grid-connected solar power by 2022. Further, Government has revised the target of Grid Connected Solar Power Projects from 20,000 MW by the year 2021-22 to 100,000 MW by the year 2021-22 under the National Solar Mission and it was approved by Cabinet on 17 June 2015.
2. National Biogas and Manure Management Program
3. Solar Lantern Program
4. Solar thermal energy Demonstration Program
5. Remote Village Lighting Program
6. National Biomass Cookstoves Initiative

7. National Offshore Wind Energy Authority
8. Green Energy Corridor
9. Repowering of Wind power projects
10. Surya Mitra Scheme

World Economic Forum's Innovation and Clean Energy Challenge

Innovation and Clean Energy is one of the challenges identified by the World Economic Forum Platform for Shaping the Future of Energy and Materials. The challenge allows companies, governments, and others to push the boundaries of innovation and expand available solutions across the energy value chain – for a better energy future. Some of the projects launched under this initiative are:

- Partnering for Sustainable Energy Innovation: The project delivers and fosters bold ideas for accelerating the pace of innovation in sustainable energy. A strategic collaboration with Mission Innovation – an alliance of 25 governments and the EU – allows companies to engage with governments to advance clean energy R&D and priority innovation issues. The project also works with interested companies and governments to establish a Global Sustainable Energy Innovation Fund, blending public and private sources of capital to de-risk investors and support innovators across national borders.
- Accelerating Clean Hydrogen: Hydrogen, as an energy carrier, has the potential to contribute to the energy transition if produced sustainably. This project mobilizes key stakeholders to accelerate the transition to a clean hydrogen economy. The Hydrogen Council – initiated at the Annual Meeting 2017 – has since been working to scale up public-private collaboration on clean hydrogen.
- Accelerating Carbon Capture Utilization and Storage (CCUS): The penetration of renewable energy systems is not fast enough to abate carbon dioxide emissions to the levels required. This project aims to provide a framework where innovators, policymakers and the finance community can collaborate to deploy CCUS faster and replicate good practices in new regions and industries.

Sources and References

1. Wikipedia (Wikipedia.com) : Renewable Energy, Photovoltaic cell, Solar Cell, Solar Cell efficiency, Reflectance, Wind Power, Hydel Power
2. Energy Auditing and Demand Side Management by N.G.Ajjanna
3. Ecree.org
4. Livemint.com
5. Doddamallappanavar, Shweta & Haveri, Deepa & Jambotkar, Chaitanya. (2019). Energy Management System Using Renewable Energy Sources. International Journal of Trend in Scientific Research and Development.
6. Eltamaly, Ali & Mohamed, Mohamed & Farh, Hassan M. H. & Alolah, Abdulrahman. (2015). Energy Management and Renewable Energy Integration in Smart Grid System.
7. Teriin.org
8. Nationalgeographic.com
9. World Economic Forum's Shaping the Future of Energy and Materials: www.weforum.org/projects/innovation-and-clean-energy