

An overview of renewable energy developments and prospects in India

Meena Kumari

Researcher in Physics , Village Rampura , Distt. Rewari, Haryana (India)

ARTICLE DETAILS

Article History

Published Online: 10 October 2018

Keywords

Renewable Energy, Development, Prospects, India, solar photovoltaic

ABSTRACT

Promoting renewable energy in India has assumed great importance in recent years in view of high growth rate of energy consumption, high share of coal in domestic energy demand, heavy dependence on imports for meeting demands for petroleum fuels and volatility of world oil market. A number of renewable energy technologies (RETs) are now well established in the country. The technology that has achieved the most dramatic growth rate and success is wind energy; India ranks fourth in the world in terms of total installed capacity. India hosts the world's largest small gasified programme and second largest biogas programme. After many years of slow growth, demand for solar water heaters appears to be gaining momentum. Small hydro has been growing in India at a slow but steady pace. Installation of some of the technologies appears to have slowed down in recent years; these include improved cooking stoves (ICSs) and solar photovoltaic (PV) systems. In spite of many successes, the overall growth of renewable energy in India has remained rather slow. A number of factors are likely to boost the future prospects of renewable energy in the country; these include global pressure and voluntary targets for greenhouse gas emission reduction, a possible future oil crisis, intensification of rural electrification program, and import of hydropower from neighboring countries.

1. Introduction

India's commercial energy consumption has been growing fast in recent years keeping pace with high economic growth rate. Table 1 shows the growth in commercial energy consumption of India and a few other selected countries and regions during the period 1995–2005. India had the second highest percentage growth in energy consumption among the listed countries after China during this period. India depends heavily on coal and oil for meeting its energy demand. The shares of different sources in primary conventional energy consumption in 2005 were: coal – 55.0%; oil – 29.9%; natural gas – 8.5%; hydroelectricity – 5.6%; and Nuclear energy – 1.0% [1]. This pattern of energy consumption is highly problematic for the country. Coal is a polluting fuel and is the biggest source of national greenhouse gas emissions; its use needs to be curtailed for reducing emissions of both greenhouse gases and local air pollutants. India depends heavily on imports for meeting its domestic oil requirements; imports accounted for 72% of India's total oil consumption in 2004–2005 [2]. As a result of growing import, India's oil import bill has also been growing rapidly; the bill was INR 1717 billion (US\$ 39 billion) in 2006. Growing oil import would imply even greater economic burden in the future and greater energy insecurity. The above obviously shows the need to reduce India's dependence on both coal and oil. Currently, India's per capita energy consumption is very low; in 2003 the consumption was 439 kgoe per capita compared with 1090 kgoe per capita in case of China, 4052 kgoe per capita for Japan and 1688 kgoe per capita for the world [2] Energy consumption of India is therefore expected to continue growing significantly in the future. The only practical options for enhancing energy security and reducing coal consumption as well as oil import bill would be improving efficiency of energy use and promoting renewable energy. This paper presents the highlights of historical development of renewable energy

technologies (RETs) in India and related issues. It also compares the development of RETs in India with developments outside the country and explores their future prospects.

2. Review of Literature

The United States right now depends vigorously on coal, oil, and regular gas for its vitality. Fossil fuels are non-renewable that is, they draw on limited assets that will in the long run lessen, turning out to be excessively costly or too naturally harming, making it impossible to recover. Consistently human movement dumps approximately 8 billion metric huge amounts of carbon into the air, 6.5 billion tons from fossil energizes and 1.5 billion from deforestation. The colossal utilization of fossil powers has brought about noticeable harm to nature in different structures. It makes parcel of environment issue lastly our biological cycle will be influenced. The vitality business needs to get more from existing fields while keeping on looking for new assets. Because of mechanical headway vehicles are made with enhanced fuel productivity furthermore consummate cross breed vehicle are made. Additionally the enhancements are required so that wind, sunlight based and hydrogen can play more significant sources in the vitality field. The many sorts of renewable vitality assets, for example, wind and sun powered vitality are continually recharged and will never run out that is one advantage. Most renewable vitality comes either straightforwardly or in a roundabout way from the sun. Daylight, or sunlight based vitality, can be utilized straightforwardly to heat and lighting homes and different structures, for creating power, and for boiling hot water warming, sun based cooling, and an assortment of business and modern employments.

Another preferred standpoint utilizing renewable assets is that they are dispersed over a wide geological zone,

guaranteeing that creating districts have admittance to power era at a steady cost for the long haul future. The sun's warmth likewise drives the winds, whose vitality, is caught with wind turbines. At that point, the winds and the sun's warmth make water vanish. At the point when this water vapor transforms into rain or snow and streams downhill into waterways or streams, its vitality can be caught utilizing hydroelectric power. Alongside the rain and snow, daylight causes plants to develop. The natural matter that makes up those plants is known as biomass. Biomass can be utilized to deliver power, transportation fills, or chemicals. The utilization of biomass for any of these reasons for existing is called bio vitality. Hydrogen additionally can be found in numerous natural mixes, and in addition water. It's the most bottomless component on the Earth. Be that as it may, it doesn't happen normally as a gas. It's constantly consolidated with different components, for example, with oxygen to make water. Once isolated from another component, hydrogen can be scorched as a fuel or changed over into power. Not all renewable vitality assets originate from the sun. Geothermal vitality taps the Earth's inner warmth for an assortment of employments, including electric power creation, and the warming and cooling of structures. What's more, the vitality of the sea's tides originates from the gravitational draw of the moon and the sun upon the Earth. Actually, sea vitality originates from various sources. Notwithstanding tidal vitality, there's the vitality of the sea's waves, which are driven by both the tides and the winds. The sun additionally warms the surface of the sea more than the sea profundities, making a temperature distinction that can be utilized as a vitality source. Every one of these types of sea vitality can be utilized to deliver power.

3. Renewable energy is important because of the benefits it provides

1. **Ecological Benefits:** Renewable vitality advancements are perfect wellsprings of vitality that have a much lower natural effect than ordinary vitality advances.
2. **Vitality for Ours Children (Sustainability):** Renewable vitality won't run out. Ever, different wellsprings of vitality are limited and will some time or another be exhausted.
3. **Occupations and the Economy:** Most renewable vitality speculations are spent on materials and workmanship to fabricate and keep up the offices, as opposed to on expensive vitality imports. Renewable vitality ventures are typically spent inside the United States, every now and again in a similar state, and regularly in a similar town. This implies your vitality dollars remain home to make employments and fuel neighborhood economies, instead of going abroad. In the meantime, renewable vitality advancements created and worked in the United States are being sold abroad, giving a support to the U.S. exchange shortage.
4. **Vitality Security:** After the oil supply disturbances of the mid 1970s, our country has expanded its reliance on remote oil supplies as opposed to diminishing it.

This expanded reliance impacts more than simply our national vitality approach.

4. Accessibility of renewable energy resources

Renewable Energy sources are not drained, and it is dispersed over a wide geological region, these assets are immediately reestablished through regular process. It won't make any natural contamination issues. The primary favorable position of utilizing renewable asset is it is accessible consistently. By an one time speculation we can draw vitality for a long time without influencing the earth.

A. Sun based Energy: Sun based Energy has the best potential for giving spotless, safe, and dependable power. The sunlight-based vitality falling on the Earth's mainlands is more than 200 circumstances the aggregate yearly business vitality right now being utilized by people [4]. The administration began sun powered power appropriation with sponsorships. A shopper who introduces a sun powered board cluster on a house can offer surplus vitality to the nearby utilities. The sun based board cost, diminished to half, which would make sun oriented Powered Electricity cost tantamount with different sorts of fuel, is conceivable inside the following decade [50]. Sun powered Energy can be delegated two sorts

1. Detached sun powered and
2. Dynamic sunlight based. Detached sunlight based vitality is making immediate and circuitous utilization of warm energies from the sun. Circuitous utilization of Energy is conceivable just in building (or) structures.

A southern presentation of a building ensures the greatest introduction of the sun's beams. Extraordinary metal leaf covering over windows and rooftops can shut out the sun amid the midyear months. Unique warm sunlight based authorities can course water through the gathering unit that gather the sun's warm vitality with the end goal of warming the water for utilize [6]. Dynamic Solar Energy is the utilization of the sun's Electro attractive radiation in creating Electrical Energy. For the most part semi-conductor silicon Boron sun powered chips are utilized for this. The issue of these chips one that they have low Efficiency proportion and must be utilized as a part of providing Energy needs of little gadgets (i.e. calculators, watches, radio etc.)as shown in Fig.1

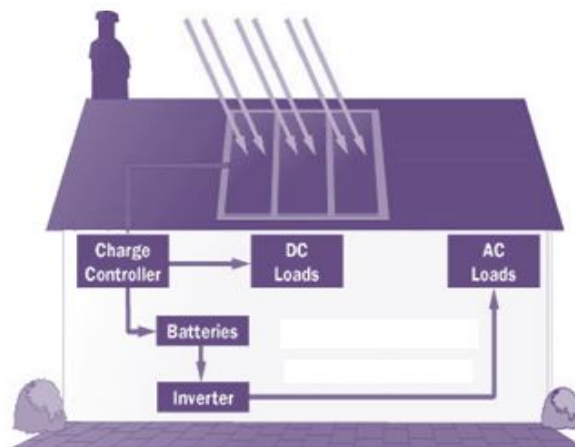


Fig 1: Solar energy mechanism at the unit

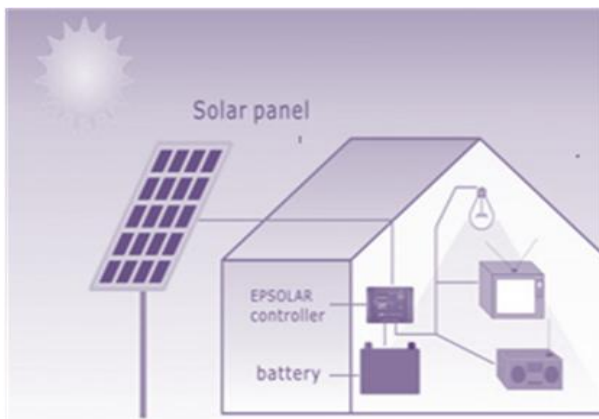


Fig 2: Solar energy mechanism at the unit

B. Wind Energy: Twist, at last determined by air, is simply one more method for gathering Energy. Sun likewise warms the environment, which produces wind. It deals with overcast days and Rainy season too. The area of wind turbines is an essential variable, which impacts the execution of the machine. The windmills are for the most part situated at the highest point of a tower to statures around 30 m. To maintain a strategic distance from turbulence from one turbine influencing the twist stream at others it is situated at 5-15 times cutting edges breadth. Windmills are working both in flat pivot and vertical hub. The essential mechanics of the two frameworks are comparative. Twist disregarding the cutting edges is changed over into mechanical power, which is sustained through transmission to an electrical generator. Wind turbines won't work in winds underneath 13 km 60 minutes. They work best where the wind speed midpoints 22 km 60 minutes. The larger part of wind turbines delivered right now are level hub turbine with three sharp edges, 15-30 m measurement, creating 50-350 Kw of Electricity. Wind vitality creates no air or water contamination, includes no harmful or unsafe substances, and represents no danger to open wellbeing.

C. Biomass Energy: Biomass is the most vital hotspot for vitality preparations provided by horticulture. Compelling saddling of bio-vitality can invigorate whole provincial milieu in a nation like India where nature offers different sorts of biomass. This vitality is additionally accessible as biodegradable waste, which is the rejected segment of accessible biomass. Biomass vitality eludes to fills produced using plants and creature squanders. The Biomass asset is natural matter in which the vitality of daylight is put away in substance bonds. At the point when the bonds between carbon, hydrogen and oxygen atoms are broken by processing, burning (or) deterioration these substances discharge put away vitality. Biomass vitality is produced when natural matter is changed over to Energy. In liquor maturation, the starch in natural matter is changed over to sugar by warming. This sugar is then aged lastly ethanol is distiller and after that mixed with another fuel. A vigorous assimilation changes over biomass, particularly squander item, for example, city strong waste and market squander, in this procedure, the facultative microscopic organism's breakdown the natural material without oxygen and deliver methane and carbon

dioxide. Bioconversion is a non-dirtying, naturally plausible and financially savvy prepare [8]. The gushing and digester buildups are rich in nitrogen and phosphorus, which can be reused back to the dirt as manure [9]. By utilizing this technique we can infer 70% of the vitality. The biomass is blended with water and put away in a hermetically sealed tank. The natural squanders (Municipal Solid Waste) are gathered independently and dried common technique and destroyed to the most extreme molecule size of 2 – 4 mm. This was put away in a plastic compartment at room temperature and was portrayed and it was utilized amid all anaerobic processing treatment. Household sewage was gathered from a school grounds before transfer. It was utilized as a part of all anaerobic processing tests for weakening the feedstock to accomplish the required aggregate solids fixation for the present examination. Investigations were done in 5 lit. Limit cluster sort reactor working in semi ceaseless mode with day by day sustaining. The digester was worked at room temperature at steady water driven maintenance time of 25 days with various natural stacking rate. To begin with, the digester was started by accusing of 2.75 lit. of bolster stocks (2% TS) alongside 2 lit. Of nourish ooze. The digester was kept up anaerobic partner and adjustment was to happen for two weeks. Amid this adjustment period, pH was kept up in the scope of 6.5 to 7.5 by including sodium hydroxide. The pH and gas generation were measured each day. It was found that the greatest biogas creation is 0.36m³/kg of VS included/day at the ideal natural stacking rate of 2.9 kg of VS/m³/d. In Chennai the administration set up a power plant utilizing vegetable waste as fuel. Every day 40 tons of market waste will be utilized for the power plant. The power plant will create around 4800 units of power/day. The gas includes 65% of methane and 35% of carbon di oxide, and is moved into a gasholder lastly electrical vitality is delivered. The power produced from the plant will be sold at Rs.3.15/unit

D. Tidal Power: Seas cover Two Thirds of the Earth's surface. This water is inconceivable supply of renewable vitality. India is normally situated in seashore side and secured 3 sides via ocean, the development of the water at the seaside front in dynamic vitality that can be changed over into Electrical vitality. The vitality spread out along the thousands of km of coasts, in positive area, the vitality thicknesses can normal 65 MW/mile of coastline a sum which can prompt to conservative wave created Electricity. The least expensive technique to draw tidal power is that the wavering water sections utilize the drive of waves entering a settled gadget to produce Electricity. The waves entering the tied down pack air in a vertical pipe. This packed air can be utilized to just infer a turbine generator creating Electricity. The fundamental issue of wave power plants is twister and extreme tempests. Amid this period the plant is not working.

E. Geothermal Energy: Geothermal vitality is the warmth from the Earth. It's perfect and maintainable. Assets of geothermal vitality run from the shallow ground to boiling point water and hot shake found a couple of miles

underneath the Earth's surface, and down significantly more profound to the greatly high temperatures of liquid shake called magma. Everywhere, the shallow ground or upper 10 feet of the Earth's surface keeps up an about consistent temperature somewhere around 50° and 60°F (10° and 16°C). Geothermal warmth pumps can take advantage of this asset to warmth and cool structures. A geothermal warmth pump framework comprises of a warmth pump, an air conveyance framework (ventilation work), and a warmth exchanger-an arrangement of funnels covered in the shallow ground close to the building. In the winter, the warmth pump expels warm from the warmth exchanger and pumps it into the indoor air conveyance framework. In the mid-year, the procedure is turned around, and the warmth pump moves warm from the indoor air into the warmth exchanger. The warmth expelled from the indoor air amid the mid-year can likewise be utilized to give a free wellspring of boiling hot water [10].

5. Environmental problems in non-renewable energy resources

Fossil powers are coal; oil and common gas, have started from the disintegration of natural matter in or on the Earth. Coal is the most noticeably bad guilty party among fossil powers regarding CO₂ per unit of vitality produced. Industrialized nations create 20% to 30% of their vitality from coal. Petroleum is gotten from rich natural particles in the residue shape. It discharges sulfur substance and carbon monoxide lastly drives Acid rain. Common gas is burnable blend of methane and different hydrocarbons. Methane is exceedingly destructive one. The fossil fills are creating taking after vaporous poisons in the air.

A. Carbon Dioxide: Carbon Dioxide is in charge of 55% of a worldwide temperature alteration. The principle sources are fossil fuel blazing (77%) and deforestation (23%). The barometrical Carbon di-oxide as of now introduces about a 30% change on the planet. At last, this could expand the normal worldwide temperature by around 1°-5° C. Consistently the normal worldwide surface temperature rises around 0.3°-0.6°C. The Nitrogen oxides are in charge of around 35% of corrosive rain. Methane is in charge of around 20% of the green house impact. This is primarily transmitted from smoldering of coal and normal gas releases, characteristic gas connected with oil generation and spillage of petrol. In Thermal power plants the coolant water is released into streams (or) lakes. The water body all of a sudden builds the temperature and losing its oxygen holding limit i.e., Dissolved oxygen is decreased, so it is straightforwardly influencing the sea-going living beings.

B. Existing available renewable resources: In constrained accessible innovation and efficient thought to trap and store the renewable energies when we are in copious supply in the region where other needed to focus much. The generation of fuel increments, that option vitality sources in India are restricted utilizes and generation .The reason is the nearness of oil and the

absence of natural mindfulness. Also, a couple interest in the field of renewable vitality.



Fig. 3

The sorts of renewable vitality in India are hydropower dams and supplies (LIMITED) .Solar vitality for road lighting (as appeared in picture roar Fig. 3). What's more, wind power extends under usage, however in restricted areas relying upon the potential accessibility of wind and these destinations on the west side, the south-west and north-west of the nation and close to the waterfront regions (specific space in India in the southern city of Basra).

6. Renewable and alternative energy sources

Genuine renewable vitality sources are vitality supplies that are refilled by characteristic procedures in any event as quick as we utilize them. All renewable vitality comes, at last, from the sun. We can utilize the sun straightforwardly (as in sunlight based warming frameworks) or in a roundabout way (as in hydroelectric power, wind power, and power from biomass powers). Renewable vitality supplies can get to be distinctly depleted in the event that we utilize them quicker than they get to be recharged: the majority of England's woodlands were chopped down for fuel before the English began utilizing coal. On the off chance that utilized admirably, in any case, renewable vitality supplies can keep going forever. There are different contrasting options to our normal vitality sources that are not renewable. Despite the fact that these are "elective vitality" as opposed to "renewable vitality", they utilize the vitality we have more effectively than more established advances. In doing this, they help us make our current vitality supplies last more and give us additional time before we come up short on put away fossil and nuclear energizes. The utilization of renewable and option vitality sources can spare us cash, guarantee that our grandchildren and extraordinary grandchildren will have enough vitality, and free us from the instabilities of relying upon vitality supplies outside the United States.

Sorts of Renewable and Alternative Energy: There are a few renewable vitality sources that are being used today. Recorded beneath are brief depictions of these assets; later we will talk about how some of these can be utilized as a part of private applications.

Hydropower: Hydropower speaks to one of the most established and biggest renewable power sources and records for near 10% of our country's power. Existing

hydropower limit is around 80,000 megawatts (MW – one million watts or one thousand kilowatts). Hydropower plants change over the vitality of streaming water into power. This is essentially done by damming streams to make expansive supplies and afterward discharging water through turbines to create power. Hydropower brings about no emanations into the climate yet the way toward damming a waterway can make critical biological issues for water quality and for fish and untamed life natural surroundings.

Biomass: Biomass is second to hydropower as a pioneer in renewable vitality generation. Biomass has a current limit of more than 7,000 MW. Biomass as a fuel comprises of natural matter, for example, modern waste, rural waste, wood, and bark. Biomass can be singed straightforwardly in exceptionally composed power plants, or used to supplant up to 15% of coal as a fuel in customary power plants. Biomass smolders cleaner than coal since it has less sulfur, which implies less sulfur dioxide will be radiated into the atmo-circle. Biomass can likewise be utilized in a roundabout way, since it produces methane gas as it rots or through a cutting edge handle called gasification. Methane can deliver control by blazing in an evaporator to make steam to drive steam turbines or through interior ignition in gas turbines and responding motors. The biggest utilization of biomass vitality in Virginia is the woods items industry. Furniture plants, sawmills, and paper processes for the most part smolder their wood waste to deliver warmth and power. Numerous property holders utilize kindling or pellets for winter warm.

Geothermal: Geothermal electric limit in the United States is more than 3,000 MW. Geothermal power plants utilize high temperatures profound underground to create steam, which then powers turbines that deliver power. Geothermal power plants can draw from underground repositories of boiling hot water or can warm water by pumping it into hot, dry shake. High underground high temperatures are gotten to by boring wells, at times more than a mile profound. In one sense, this geothermal vitality

is not renewable, since at some point later on the center of the earth will cool. That time is so distant (countless years) that that we consider it renewable. Most geothermal power plants are situated in the western United States; however some coastal areas of Virginia (close Wallops Island) have geothermal power potential. Geothermal warmth pumps utilize compressors to pump warm out of the earth (for winter warming) or into the earth (when running as aeration and cooling systems in summer). The vitality they pump into and out of the earth is renewable, since it is supplanted by the cycle of the seasons. The vitality that runs the compressor can either be renewable or conventional.

Sun oriented Energy: Sun oriented vitality comes straightforwardly from the force of the sun and is utilized to create power, to deliver warm, and for light. Sun oriented speaks to a little share of the electric market in the United States – around 1/2 of one percent of electrical limit. Sun based's commitment to warming and lighting is much bigger. Sun oriented electric power can be created either by power plants utilizing the sun's warmth or by photovoltaic (PV) innovation, which changes over daylight specifically to power utilizing sunlight based cells. PV innovation is more down to earth for private utilize. Frameworks to utilize the warmth of the sun straightforwardly can be either dynamic or aloof. In dynamic frameworks, air or fluid flow through sun based authorities and bring warmth to where it is utilized. In latent frameworks, structures are worked with windows and warmth retaining surfaces set up to augment sunlight based warming in winter. Either innovation is reasonable for private utilize. Frameworks to straightforwardly utilize the light of the sun are generally normal. The most normal gadget for utilizing daylight is the window, yet sky facing windows and bay window tubes are likewise utilized.

Wind Power: Wind vitality speaks to 4,700 megawatts (MW) of introduced electric limit in the United States. Wind has been the quickest developing vitality source in the U.S. in the course of the most

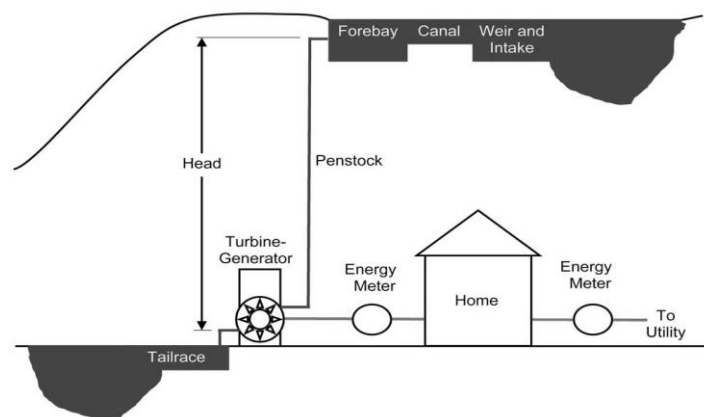


Figure 4- Grid-connected residential micro hydropower system

7. Renewable energy and energy efficiency loan program

The Virginia Housing and Redevelopment Authority regulate a low-intrigue credit program for low and direct salary mortgage holders. This program, made in 1978, gives

advances to home repairs that diminish vitality utilization or decrease reliance on routine vitality sources. All renewable vitality advancements are qualified and this incorporates detached sun oriented space warm, dynamic sun based water

warm, dynamic sun based space warm, sun based warm power, photovoltaic frameworks, wind vitality frameworks, biomass, hydropower, geothermal, and squander. The financing cost is 6.75% and credit sums run from \$1,000 to \$25,000 for terms from 6 months to 20 years.

Nearby Option Property Tax Exemption: This Virginia statute, segment 58.1-3661 from the Code of Virginia permits any district, city, or town to absolved sun powered vitality gear or reusing hardware from neighborhood property charges. Private, business, or modern property is qualified. The statute characterizes sun powered vitality gear as any "application that would somehow require a routine wellspring of vitality". This includes sunlight based space warm, sun powered water warm, sun oriented warm power, and photovoltaic frameworks. Contact your nearby Commissioner of Revenue to check whether your area offers the exemption and for additional data.

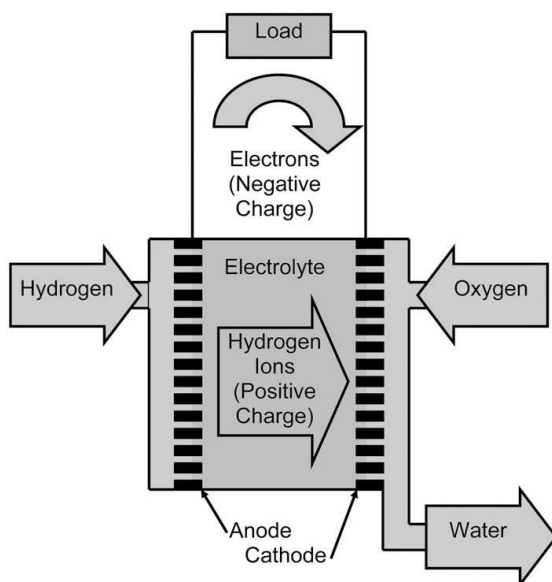


Figure 5: Schematic of basic hydrogen-oxygen fuel cell operation

Net Metering: "Net metering" permits clients to get the full retail estimation of any overabundance power they produce from their sun based, wind, or hydroelectric framework. When you utilize control from the framework you pay for it, however when you supply abundance renewably-produced energy to the network your electric meter basically turns in reverse and subtracts kilowatt hours from your bill. The law requires all utilities under the ward of the State Corporation Commission to offer net metering to private frameworks of 10 kW or less and to non-private frameworks of 500 kW or less. As far as possible the measure of net metered era in a specific utility circulation domain to 0.1% of the previous year's pinnacle power request. Rate payers can apply the credit for power created from their framework to the next month; be that as it may, toward the end of the year, any abundance era is allowed to the utility. Contact your neighborhood utility supplier or the Virginia Department of Mines, Minerals and Energy for more data.

8. Vitality Tips and Recommendations

1. Consider the utilization of renewable vitality frameworks that deliver clean and non-dirtying vitality.

The underlying expense or venture might be high however over the long haul the reserve funds can be noteworthy. You will likewise be making a critical responsibility to sparing our normal assets and saving nature.

2. On the off chance that you have a stream on your property, you might have the capacity to build up a little miniaturized scale hydropower framework that can create enough power to control your home.
3. Space warming is an ease route in which to incorporate biomass into a private renewable application.
4. Geothermal warmth pumps, which utilize the warmth of the earth, to give warming and cooling to the house are three circumstances more effective than traditional vitality productive heaters.
5. Sun based electric frameworks (PV frameworks) utilize the force of the sun to create power. Sun based boards mounted on your rooftop or close to your home can give clean, non-contaminating, and renewable vitality to control your home.
6. Little private wind vitality frameworks give a clean, non-contaminating wellspring of power. You should have an adequate normal yearly wind speed and enough establishment space for twist vitality to be successful.
7. Consider utilizing half and half power frameworks, which join distinctive renewable vitality sources to create power.
8. Power modules consolidate hydrogen and oxygen without ignition to deliver power. They are proficient, and when energized with unadulterated hydrogen their exclusive discharge item is water vapor. They speak to an energizing new innovation that is still a couple of years away yet may speak to the private power wellspring without bounds.
9. Exploit existing projects to balance the cost of renewable vitality frameworks and to get administrations and ability.
10. Remember that lessening vitality use through preservation and expanded proficiency is quite often a less expensive option than introducing a restore capable vitality framework.

9. Conclusion

India's energy consumption is poised to increase rather rapidly in the years to come for supporting and sustaining the economic growth that the country is now enjoying. Meeting the growing energy demand based on the current pattern of energy supply, which is characterised by heavy dependence on coal and imported oil, will become increasingly difficult in view of the needs to keep GHG emissions and crude oil import bill low. Thus the importance of renewable energy in the case of India is likely to grow monotonically in the future. In spite early initiation of renewable energy programmes, India lags behind certain other countries and regions in the case of some RETs. The role of renewable energy in future energy supplies was probably under-estimated because of lack of reliable potential estimates of most of the renewable sources; this was compounded by the fact that the potential of some of the sources, for example biomass was grossly under-estimated.

India has the world's largest small gasified programme and the second largest biogas and ICS programs. However, a large number of the installed biogas plants are not in use any more; of the 35 million ICSs installed so far, it is estimated that less than 6 million are in use at present. Solar thermal and PV systems are technically well established in India. However, their installation has been rather low in comparison with certain other countries, regions and world as a whole. Programmes on alternative liquid fuels (e.g., ethanol and biodiesel) have been

launched in India only recently. Given the growing interest in these fuels worldwide and India's heavy dependence on imported oil, it is likely that interest in these fuels will grow rapidly in the country. India's most successful renewable energy programme so far is wind power generation. Involvements of the private sector, enabling environment created by the government and low cost of wind power have contributed to the success of wind power in the country.

References

1. R.V.Shahi,(2005) " Sustainable Development and Innovation in the energy sector" Indian power sector, Challenge and Response, Excel books A-45, Narain Phase-I
2. Sarica K., Or I.,(2007), Efficiency assessment of Turkish power plants using data envelopment analysis, *Energy* 32, 1484–1499.
3. Wing I., Eckaus R.,(2004). "Explaining Long-Run Changes in the Energy Intensity of the U.S. Economy,". Report No. 116. The MIT Joint Program on the Science and Policy of Global Change
4. Berglund C., Söderholm P., (2006). "Modeling technical change in energy system analysis: analyzing the introduction of learning-by-doing in bottom-up energy models". *Energy Policy* 34, 1344–1356.
5. Frei C., Haldi P., Sarlos G., (2003). "Dynamic formulation of a top-down and bottom-up merging energy policy model". *Energy Policy* 31, 1017–1031.
6. Sorell S., Dimitropoulos J.,(2008). The rebound effect: Microeconomic definitions, limitations and extensions. *Ecological Economics* 65, 636–649.
7. Alcantara V., Duarte R., (2004). Comparison of energy intensities in European Union countries. Results of a structural decomposition analysis. *Energy Policy* 32, 177–189.
8. Greening L., Boyd G., Roop J., (2007). Modeling of industrial energy consumption: An introduction and context, *Energy Economics* 29, 599–608.
9. Sari Siitonen, & Mari Tuomaala, & Pekka Ahtila, (2010) Variables affecting energy efficiency and CO2 emissions in the steel industry, Article provided by Elsevier in its journal *Energy Policy*, Volume:38,
10. Ernst Worrell, John A. Laitnerb, Michael Rutha and Hodayah Finmanb, (2001) Productivity benefits of industrial energy efficiency measures, Energy Analysis Department, Lawrence Berkeley National Laboratory, US Environmental Protection Agency.