ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 9, Issue, 06, pp.51838-51842, June, 2017

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

NON-CONVENTIONAL ENERGY – NEED AND SCOPE IN GLOBAL AND INDIAN SCENARIO

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ARTICLE INFO

Article History:
Received 28th March, 2017
Received in revised form
12th April, 2017
Accepted 10th May, 2017
Published online 20th June, 2017

Key words:

Non conventional energy, Global warming, nuclear, Biogas, Hydroelectric, Solar, Wind energy, Tidal power, Geothermal.

ABSTRACT

Twentieth century saw the rapid spread of conventional energy usage worldwide, which brought life changing progress and improvement in quality of life. However, this progress came with a price, global warming and attended risks of climate change, loss of habitat and rise in sea level. The need of the hour is to reduce the rate of global warming. In this article, I have briefly described the history and use of conventional energy sources and the way we can introduce new nonconventional energy sources. Nonconventional energy is expensive now, because the technology is still in research and development phase. Even though the initial cost is high, it is expected to come down because newer technologies with lower costs will be developed with wide spread use.

Citation: Rageena Joseph, 2017. "Non-conventional energy – Need and scope in global and Indian scenario", *International Journal of Current Research*, 9, (06), 51838-51842.

INTRODUCTION

The world relies on conventional energy, mainly in the form of fossil fuels for its energy needs. In fossil fuels energy is stored as carbon compounds and burning it produces CO_2 and other green gases leading to Global warming. 195 countries who attended the Paris conference on climate change in December 2015 agreed by consensus to reduce the carbon output as soon as possible and do their best to reduce global warming well below 2^0 C above preindustrial levels. The agreement will become legally binding only if at least 55 countries that produce over 55% of global carbon emissions approve it. High polluters such as China, USA, India, Brazil, Canada, Russia, Indonesia and Australia produce more than half of world's green gas emissions. Each country that ratifies the agreement will be required to set a target for emission reduction, but the amount will be voluntary. European countries such as France and Germany are in the forefront in the use of nonconventional energy. France produced 90% of its electricity from zero carbon sources. After the nuclear leak following Tsunami in Japan, Germany decided to replace nuclear energy plants with renewable energy sources.

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History of energy

Until the industrial revolution there were only primary energy sources such as fire, wind mills and sails to assist irrigation, agriculture and sea travel. In England wood was used to heat homes. When all the trees were cut down, people started burning coal. The only problem was that most coal mines were flooded and water was pumped out by steam engines. In 1765 James Watt introduced a condenser which increased the efficiency of steam engines and subsequently adapted his engines for rotary motion which increased its scope in other industries, trains and ships. Another breakthrough in energy source came when petroleum was successfully extracted from an oil well in Pennsylvania, USA in 1851 using steam powered drill by Edwin Drakes. This oil was collected in whisky barrels, and thus the barrel became the unit for petroleum. Abraham Gesner developed a process to refine Crude petroleum into a clear liquid fuel which he named kerosene, which replaced lamps burned on sperm whale oil, thus saving sperm whales from extinction. Karl Benz invented internal combustion engine in 1886 to utilise the waste petroleum after extraction of kerosene. In 1893 Rudolf Diesel invented the diesel engine (which was named after him) to use the heavier fraction of petroleum left after extraction of gasoline. Fossil fuels are yesterday's energy. All energy except nuclear energy is a stored form of sun's energy. Non-conventional energy forms except nuclear energy are renewable because they are powered by the sun which would be a constant source energy for millions of years to come.

Biomass energy

- Biogas
- Bio ethanol
- Biodiesel

Biogas is also called landfill gas because it is produced by natural degradation of bio-waste by bacterial action. Bio waste such as human and animal excreta, food waste, vegetable and plants waste and industrial waste involving organic materials can be used for generating methane gas which on combustion yield energy stored as chemical energy. Plants convert sun's energy into carbohydrates by photosynthesis which is the source of this energy. Biogas plants can be small scale, suitable for homes and hotels or large plants on an industrial scale. Large biogas plants may generate foul smell and therefore need to be away from residential areas. Bio ethanol is produced by fermentation of corn, sorghum, wheat, rice, sugarcane and potato. Some shrubs, grass and non-edible parts of plants can be used to produce cellulose ethanol. Currently 99% of bio ethanol produced is used to make E10 or gashol which contain 10% of ethanol and 90% gasoline. When 85% bio ethanol is combined with 15% gasoline we get E85 which requires special engines to use it as a fuel. Biodiesel is produced from vegetable oil such as soya bean and rapeseed oil and animal fat. By combining with petrol and diesel, bio ethanol and biodiesel reduce green gas emission. When biodiesel burns it produces 20-40% less greenhouse gases such as CO, CO_2, SO_2 and unburned hydrocarbons. However, biodiesel produces 10% more N2O than petroleum diesel.

Disadvantages of bio ethanol and biodiesel

- Deforestation. Forest is burned or cut down to plant soya bean, corn and other plants to produce biofuels. These plants are less efficient than a rain forest in absorbing CO_2 and therefore the net effect will be increased carbon emission. Deforestation can lead to loss of wild life due to habitat loss and decreased biodiversity of fauna and flora. Deforestation can lead to reduced rainfall because 90% of rain in rainforest is generated by the forest itself.
- When grains are used to produce biofuels, it become less available for human consumption and it may lead to famine.

There is a strong case for biogas where people own sufficient livestock: the dung from two cows typically suffices to meet the cooking requirements of a household. As the fuel is produced on site, there are limited distribution challenges or costs beyond the delivery of the equipment. Even though a higher initial investment is required than for the other options (and access to finance therefore needs to be provided), the absence of ongoing fuel costs mean that the annualized cost over the lifetime of the equipment is significantly lower than that for LPG. Replacing LPG with biogas in Thailand resulted in savings per household of more than $70 per year. This is most relevant in some rural and peri-urban settings especially in South Asia.

Nuclear Energy

Nuclear energy is currently produced by nuclear fission which involves radioactive substances and the end products of nuclear fission can also be radioactive. Nuclear fission is a very efficient way of power generation due the high amount of energy released by conversion of small amount of matter as evidenced by the mass energy equation $E = MC^2$. Building and maintaining a nuclear reactor is expensive and the facility needs long time and huge expenditure for decommissioning after nuclear fission is stopped. Explosion in a nuclear plant can have catastrophic consequences as happened in Chernobyl in Ukraine. We also need to take into consideration the impact of natural calamities such as earthquakes and tsunamis on immediate and long-term radiation exposure to people working in the plant and the wider population who may be affected.
Nuclear fusion on the other hand involves no radioactive substances and is safe. Since initiation of nuclear fusion requires generation of 15millon degree C temperature, currently we have no commercially usable technique to create suns here on earth. A collaboration of 50 nations including India is building a facility in Europe to test the possibility of large scale fusion reaction. Small scale fusion has been successfully achieved by several countries, so we need worldwide collaboration for technology to advance.

Nuclear Energy in India

India currently produces 5780 MWe of energy from its 21 reactors which covers 3%of domestic energy production. This fell short of the ambitious three stage nuclear programme envisaged by the founding chairman of Atomic Energy Commission of India Homi Bhabha in the 1950's through the use of Uranium and Thorium reserves. India has only 1-2% of U^{235} reserves; however, it has 25% of global reserves of Thorium. Thorium is not a fissile element however it can be transmuted to U^{233} which is used for nuclear fission. Natural Uranium in India contains only 0.7% of U^{235}, most of the remaining is U^{238}. Natural Uranium in other countries contain up to 14%U^{235}. So Homi Bhabha proposed a three-stage nuclear fission procedure to suite India's high Thorium reserves.

Bhabha's 3 stage procedure

Stage 1: Natural Uranium fuelled Pressurised Heavy Water Reactors (PHWR) to produce Plutonium. U^{235} in the natural Uranium undergoes fission producing electricity and U^{238} is converted to Plutonium 239.

Stage 2: Plutonium fuelled Fast Breeder Reactors (FBR) produce electricity and convert Thorium into U^{233}. FBR uses a mixed oxide fuel made from P^{239} recovered by reprocessing of spent fuel from stage 1 and natural Uranium. In FBR, P^{239} undergo fission to produce electricity. U^{238} in natural uranium is converted to additional P^{239}. So FBR is designed to breed more fuel than it consumes. Once enough $P^{239}$is built up Thorium ^{232} is introduced which is transmutated to U^{233}.The surplus P^{239} bred into each reactor can be used to set up more such reactors.

Stage 3: A Stage 3 reactor is a thermal breeder reactor involving a self-sustaining series of Thorium ^{232} and U^{233}fuelled reactors. Once the reactor is in full swing it can be refuelled by naturally occurring Thorium alone. However large-scale Thorium deployment is possible only after attaining the 50GW capacity from first two stages. Large scale Thorium utilisation is expected only by 2050 unless accelerated stage 1 and 2 production of nuclear fuels is achieved by imported Uranium. As there is a long delay for the direct utilisation of

Thorium, three other options are considered of which AHWR (Advanced Heavy Water Reactor) is ready for deployment. In 2014 our Prime minister urged the DAE (Department of Atomic Energy) to increase the current output of 5.3GWe to 17 GWe by 2024. In November 2015 NPCIL revised a target of 14.5GWe by 2024. This will only be possible with substantial import of Uranium. The 12thfive-year plan envisages to start work on eight 700MV PHWR, two 500MW FBR and one 300AHWR and eight light water reactors with foreign technical cooperation. Our aim is to produce 600GWe by 2050 to provide half the electricity need by nuclear power.

Hydroelectric Power

Hydroelectric power is the first large scale form of renewable energy. China is a world leader in hydroelectric power. It produces 17% of it's total energy from hydroelectric projects. The present installed capacity for India as of July 2015 is 42GWe which will provide 15.22% of total electricity generated in India. India ranks 5th in the world in terms of usable hydroelectric power potential with an estimated potential of 148GWe. With current dams in construction which will add 13GWe to a total capacity of 55GWe, this puts the total tapped capacity at 33% of available potential. Canada & Brazil harnessed around 69& 48% of their capacity, whereas SreeLanka has harnessed 96% of its capacity. Over 93% hydroelectric potential in North East India especially the Brahmaputra basin is untapped. Most of India's hydroelectric power falls in the seismic zone 5, hence careful planning and precautions are essential in building new dams.

Advantages

- Hydroelectric power is relatively cheap. It cost about 5 US cents to generate 1KW electricity from a hydro station larger than 10MW. The three Gorge dam in China is calculated to pay off its building cost within 7-8 years after construction
- Hydroelectric stations have long economic lives. Some are active even after 100 years of energy production
- It is a flexible source of energy; energy production can be increased or decreased very quickly depending on demand.
- Where a dam serves multiple purposes, hydropower generators can be added with little extra cost.
- It need only minimal labour power to run it

Disadvantages

- It can submerge large areas of land under water and cause habitat fragmentation of wild life and this may lead to loss of biodiversity.
- It can destroy local aquatic ecosystems both upstream and downstream of the dam
- Sometimes the dam gets filled with silt and this will reduce storage capacity and its ability to control floods along with causing horizontal pressure on the upstream of the dam
- The world Commission on dams has estimated that 40-80 million people worldwide has been displaced from catchment area of dams. The displaced people are not often rehabilitated.
- Submerged vegetation in the dam reservoir can release the greenhouse gas methane. Where the reservoir is large compared to power generation (less than 10Watts per square meter reservoir surface) and if the forest was not cleared prior to dam construction it produces more greenhouse gases than coal powered thermal plant.

Solar Power

Solar power is produced by the conversion of sunlight into electricity, either directly by photovoltaic cell or indirectly using concentrated solar power (CSP) which uses lenses or mirrors and tracking systems to focus large area of sunlight into a small beam. PV cell converts sunlight into electricity by photovoltaic effect which is direct current. This is converted to AC and can be used for homes and utilities or connected to grid. CSP uses heat of sun's radiation to generate electricity by conventional steam driven turbines. CSP is usually used in desert areas where large turbines can be built. It has been noticed that birds are burned to flames by this high heat generated by focussing light to one point. PV systems have low maintenance cost up to 9% of the cost of electricity, whereas CSP has up to 17% maintenance cost. The life cycle greenhouse emission of solar power is in the range of 22 and 46 gram per kilowatt per hour for solar thermal and solar PV respectively. The greenhouse gas emission can be eliminated by switching to low carbon power from renewable sources to manufacture and transport solar devices. Worldwide growth of PV cells has averaged at 40% per annum. PV systems use no fuel and operate over 25-40 years. The international conference on Solar PV investments estimates that PV system will pay back in 8-12 years. Grid parity, the point at which the cost of PV electricity is equal to or cheaper than the price of grid power is more easily achieved in areas with abundant sunlight and high cost of electricity like California in USA. Grid parity was first achieved in Spain in 2013. When PV is fed into grid, two systems of payment exists. In netmetering, the price of electricity produced is the same as price supplied to the customer. As a promotional deal in Feed in Tariff (FIT) the price paid per kilowatt hour exceeds the price of grid electricity.

Rural Electrification

Lack of electricity infrastructure is one of the main hurdles in the development of rural India. India's grid system is considerably under-developed, with major sections of its populace still surviving off-grid. As of 2004, about 80,000 of the nation's villages had not yet become electrified. Of these villages, 18,000 could not be electrified through an extension of the conventional grid. A target for electrifying 5,000 such villages was set for the Tenth National Five Year Plan (2002–2007). As of 2004, more than 2,700 villages and hamlets had been electrified, mainly using solar photovoltaic systems. Developments in cheap solar technology are considered as a potential alternative that allows an electricity infrastructure consisting of a network of local-grid clusters. It could allow bypassing (or at least relieving) the need to install expensive, long-distance, centralized power delivery systems and yet bring cheap electricity to the masses. Land is a scarce resource in India and per capita land availability is low. Dedication of land area for exclusive installation of solar arrays might have to compete with other necessities that require land. The amount of land required for utility-scale solar power plants — currently approximately 1 km^2 (250 acres) for every 40–60 MW generated — may pose a strain on India's available land resource. One alternative is to use the water surface area available on canals, lakes, reservoirs and sea for locating large capacity solar power plants. These water bodies can also provide the water needed for periodic cleaning of the solar panels. It is also possible to use the highways and rail tracks to avoid excessive cost of land nearer to load centres and minimise transmission lines cost by installing solar power plants at nearly 10 meters height above the roads or rail tracks. It would also protect the highways of damage from rain & intense summer heat and offer additional comfort to the commuters.

Over the past 10 years, cumulative wind power capacity in the United States increased an average of 30% per year, outpacing the 28% growth rate in worldwide capacity. The world has seen a new record in new wind installations, adding 64GW within the year 2015. The total wind capacity of the world has reached 435 GW. In 2015 the global growth rate was 17.2 % which was higher than the previous year (16.4 %). Amongst the top 15 markets, Brazil, Poland, China and Turkey were the most dynamic countries and saw the strongest growth rates. China has once more underpinned its role as the global wind power leader, adding 33 GW of new capacity. This represents a market share of 51.8 %. The US market saw good performance with 8, 6 GW of added capacity, the strongest growth since 2012. The table below gives a comparison of energy output of wind turbines and solar panels. Energy balance is the amount of time a wind turbine or solar panel need to generate electricity in order to make up for the amount of energy, in kWh, consumed during its manufacturing. Energy Return on Investment is the ratio of the quantity of energy supplied to the quantity of energy used in the supply process. Overall wind energy is better than solar panels in terms of impact on environment. Wind farms takes less land to install.
Hence it is better suited for India where land availability per person is much less.

Table 1. Comparison of wind and solar energy

	Vestas V90-3.0 MW Wind Turbine	Photovoltaic solar panels (PV)
Energy consumed (kWh)	4,304,221	577.5 (28,126,560)
Energy generated/year (kWh)	7,890,000	162
Total kg of C02 emitted	19,971.59	226.8 (11,046,067)
Grams of CO2/ 1kWh	4.64	70
Energy Balance	6.6 months	3.2 years
Energy Return on Investment (EROI)	36.5:1	5:1

The architecture more suitable for most of India would be a highly distributed set of individual rooftop power generation systems, all connected via a local grid. However, erecting such an infrastructure, which does not enjoy the economies of large scale solar panel deployment, needs the market price of solar technology deployment to substantially decline, so that it attracts the average family size household consumer. That might be possible in the future, because PV is projected to continue its current cost reductions and be able to compete with fossil fuel. Indian government has recently reduced the solar power purchase price from 5.79 Rs/KWh to 4.43 Rs/KWh in view of steep fall in the cost of the solar power generation equipment. The applicable tariff is after allowing either viability gap funding (VGF) or accelerated depreciation (AD) incentives. Government can provide subsidies to produce PV panels, in which case there will be reduction in the market price and this can lead to more usage of solar power in India. Power from imported coal and domestically-produced natural gas currently costs around Rs 4.5 / KWh and it is increasing with time. Experts believe that ultra-mega solar power plants like the upcoming world's largest 4,000 MW UMPP in Rajasthan would be able to produce power for around Rs 5 / KWh.

Wind energy

Wind energy is produced from the air flow through wind turbines to mechanical power generators to produce electricity. Wind power, as an alternative to burning fossil fuels, is plentiful, renewable, widely distributed, clean, produces no greenhouse gas emissions during operation, and uses little land. The net effects on the environment are far less problematic than those of non-renewable power sources. Wind farms consist of many individual wind turbines which are connected to the electric power transmission network. Onshore wind is an inexpensive source of electricity, competitive with or in many places cheaper than coal or gas plants. Offshore wind is steadier and stronger than on land, and offshore farms have less visual impact, but construction and maintenance costs are considerably higher. Small onshore wind farms can feed some energy into the grid or provide electricity to isolated off-grid locations. As of 2015, Denmark generates 40% of its electricity from wind and at least 83 other countries around the world are using wind power to supply their electricity grids. Wind power capacity has expanded to 369,553 MW by December 2014. Yearly wind energy production is growing rapidly and has reached around 4% of worldwide electricity usage, 11.4% in the European Union.

Tidal energy

Tidal energy is a form of hydropower that converts the energy obtained from tides into useful forms of power, mainly electricity. Although not yet widely used, tidal power has potential for future electricity generation. Tides are more predictable than wind energy and solar power. Among sources of renewable energy, tidal power has traditionally suffered from relatively high cost and limited availability of sites with sufficiently high tidal ranges or flow velocities, thus constricting its total availability. However, many recent[technological developments and improvements, both in design (e.g. dynamic tidal power, tidal lagoons) and turbine technology (e.g. new axial turbines, cross flow turbines), indicate that the total availability of tidal power may be much higher than previously assumed, and that economic and environmental costs may be brought down to competitive levels.

Geothermal power

Many geothermal plants are operating throughout the world. The oldest geothermal power station is in Italy. In New Zealand. Geothermal power accounts for 40% of total installed capacity. Iceland also generates most of its electricity from geothermal plants. Earth's interior is made of magna at a temperature of 1000-1200^{0}C. When surface water penetrates crust it turns into steam and come out as hot springs or geysers. Molten magma also contains water which it releases as steam which is used for producing electricity. At present geothermal energy makes a very small, but locally important, contribution to world energy requirements. This situation will not change unless important technological advances are made. Environmentally, it is probably the least objectionable form of power.

Energy Efficiency

Higher energy efficiency can reduce the energy consumed to produce the same level of energy services (e.g., a more efficient bulb produces the same light output for less energy). Energy efficiency is the key to driving the required incremental reduction in energy intensity. It has come to prominence in recent decades as one of the few "no-regret" policies that can offer a solution across challenges as diverse as climate change, energy security, industrial competitiveness, human welfare and economic development. Some developed countries and regions such as Japan, Denmark and California have been able to partially decouple economic growth from energy growth, in part due to major and sustained energy efficiency efforts. Capturing all cost-effective energy efficiency measures could reduce the growth in global energy consumption up to 55 to 75 per cent from the business-as-usual case. It would also have a significant effect in emissions: energy efficiency opportunities make up about a third of the total low-cost opportunities based on currently available technology to reduce GHG emissions globally. As more and more people have access to electricity, energy demand continues to grow: energy intensity improvements are overshadowed by economic growth. Moreover, an improvement of energy efficiency can also act as an incentive to raise consumption. One reason is that because of energy efficiency improvements, energy services may become cheaper. For example, a more fuel-efficient car may result in more driving.

A second reason, especially relevant for developing countries, is that certain forms of energy use are supply-constrained. For example, in case the latent demand for electricity exceeds the supply, electricity savings because of more efficient equipment can open up the opportunity to use additional electricity-consuming equipment, and the net electricity savings effect is nullified. The combination of the two mechanisms is called the rebound effect. Measurements in developed countries suggest rebound effects in the order of 10-20 per cent of the energy saving, but for developing countries the rebound effects may be more substantial. While the energy savings and carbon saving effect may be partially offset by the rebound, an increase in energy efficiency will result in clear improvements in terms of access, welfare and economic growth. Most of energy demand growth is expected to come from lower-middle-income countries such as China and India, driven by rapid industrialization and an increasingly wealthy population with a rising demand for cars, household appliances and other energy-consuming products. In most countries, the untapped potential for improvements is available across both supply and demand. A significant opportunity exists in the power sector in the developing world to improve generation efficiency and reduce transmission and distribution losses, and thereby reduce the amount of primary energy (e.g., coal, gas, oil) consumed for the same output. In many ways, the supply side potential is easier to capture in the short- to medium-term, as there are fewer institutional barriers. Improving power sector efficiency is also directly linked to improving energy access, as discussed above. On the demand side, there are opportunities across all sectors of the economy to improve energy efficiency by reducing final energy consumption, with the largest opportunities in industry, buildings and transport. For instance, a UNIDO project funded by the Global Environment Facility (GEF) on motor systems energy efficiency in China yielded on average 23 per cent improvement with a payback period of well below two years. Energy efficiency can save money and reduce carbon emissions while maintaining economic output. It should therefore be a major global priority.

Conclusion

Over reliance on fossil fuels for energy is because it is easily available and the technology for it's extraction and use is century old and therefore well developed and currently in use globally. The downside is high carbon emission and the resources are limited and therefore will not last long into future. The new strategy should be to gradually wean off fossil fuel with mixture of renewable energy sources with an emphasis on local availability and cost of production. Rapid industrial development in China led to increased use of coal for electricity production which led to severe air pollution affecting millions of people in major cities. Since coal will continue to be used in steam turbines to generate electricity carbon capture technology should become part of the thermal power plants. Nuclear energy should be part of renewable energy portfolio. However, it needs huge infrastructure and global cooperation for its safe use. Other forms of renewable energy except hydropower can be implemented in a shorter term. We should aim for an energy portfolio which includes energy sources which are currently available such as fossil fuel and a mix of renewable energy sources which can be built on short term and long-term basis. Energy forms such as solar, wind and biofuels can be made available in short term, whereas nuclear power and hydroelectric projects need long term planning.

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