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Sustainable Energy Sources with Their Limitations

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Abstract: The three basic needs essential for survival of human are food (including water), clothing and shelter. However, the forth need in today's world, would be an electricity. The greatest scientific achievement of the nineteenth century is the discovery of electricity. The twentieth century is making the use of electricity so extensively that it has almost changed the face of the earth. The list of applications of electricity for human is unending. It is the life-blood of modern day world. The rapid industrialization and growth in human population has brought the consumption of electricity to a very high level.

As per Hinduism's sacred literature, great elements (Mahabhuta / tatva) are fivefold; i.e. space, air, fire, water & earth. All these five Mahabhutas are the basic sources of energy for life on earth. These are Vedic gods & worshipped since ancient time. Today, electric power is generated from all these elements; like power stations based on water (Hydro), Fire (Thermal), Air (Wind) & Space (Solar) and these are in use. The geo-thermal based power stations are in primary stage which is using direct heat inside the earth. Ironically, fossil fuel resources are limited. The fossil fuels – coal, petroleum and natural gas – provide most of our needs of energy and coal used to be major source of energy. If production and consumption of coal continue further, proven and economically recoverable world reserves of coal would last for about 150 years. Coal is the largest source of carbon dioxide emissions in the world. According to IEA Coal Information (2007) world production and use of coal have increased considerably in recent years. Therefore the single most important action needed to tackle the climate crisis is to reduce CO2 emissions from coal.

Today power industry is confronting challenges with seemingly conflicting goals – depleting resources, dependable survive and affordable rates etc. Different energy conversion technologies have their applications, but no single option does it all. Wind, solar and hydro options i.e. renewable sources of energy don't use any fuel, so shouldn't we just rely on these technologies? All above technologies have their own limitations. The single, largest operating cost, for a gas, oil or coal fired electrical generating station is a fuel. The option of atomic power is also not a viable solution due to availability of raw material, heavy installation cost and safety from radiation hazards.

A sustainable energy program must balance the demands of today with the needs of future generations. It must be environmentally sensitive, economically viable, and benefit the well being of the community. By educating the community about the environmental and health effects of conventional energy production, as well as the possibilities held by renewable energy, the plan satisfies all three of these sustainability guidelines.

In this paper the different sources of electric power have been studied and evaluated to have sustainable energy sources in future with their limitations, advantages and disadvantages etc.

I. Introduction

Earth is, the third-closest planet to the Sun, the densest planet in the Solar System, the largest of the Solar System's four terrestrial planets and the only celestial body known to accommodate life. There are millions of species, including a global population of humans. These living creatures are supported and nourished by the earth's biosphere and minerals. Earth was formed around four and a half billion years ago. Within its first billion years, life appeared in oceans and began to affect its atmosphere and surface, promoting the proliferation of aerobic as well as anaerobic organisms and causing the formation of the atmosphere's ozone layer. This layer and Earth's magnetic field block the most life-threatening parts of the Sun's radiation, so life was able to flourish on land as well as in water. Since then, Earth's position in the Solar System, its physical properties and its geological history, have allowed the life to persist.

When astronauts first went into the space, they looked back at our Earth for the first time, and called earth as the 'Blue Planet' since the 70% of earth is covered with ocean and remaining 30% is with the solid ground, rising above sea level. Although water features in everyone's daily lives, this fact was a relatively dry statistic until it was reinforced in the pictures of Earth taken by these first astronauts.

Geologically fossil fuels (coal and petroleum) have been originated from very old-buried (more than hundreds of million years old) of plants, animals and microorganisms and overlaid with sediments. This burial protected these vegetation and microorganism from oxygen, which would have completed its breakdown, and preserved to form as coal and petroleum. Coal originated from plants & trees, whereas petroleum & natural gas originated from marine organism. Chemically, all fossil fuels consist largely of hydrocarbons, which are compounds composed of hydrogen and carbon.

The energy sources (Energy Mix) for electric power generation in India as per data of June'2014 is as under:

Source	Total Capacity(MW)	Percentage
Coal	148,478.39	59.51
Hydroelectricity	40,730.09	16.33
Renewable energy source	31,692.14	12.70
Natural Gas	22,607.95	9.06
Nuclear	4780	1.92
Oil	1,199.75	0.48
Total	**249,488.32**	100.00

From above statistics it is obvious that coal is a potential energy substitute in India.

Although Coal is the most difficult to extract and burn, it is most economical and abundantly available in earth compared to other fossil fuels but not unlimited. It fueled the industrial revolution and has historically been the fuel of choice in many countries for power generation, manufacturing steel & cement etc. The demand of electricity growing many folds day by day and at this rate, the coal deposit as well as other fossil fuels would be consumed in next few decades / centuries. The millions of years were required the fossil fuels to take their usable form however they will be exhausted so fast at this rate of consumption. Moreover the high rate of consumption of fossil fuels will endanger the stability of environmental parameters which are required for existence of human / living species on earth, due to emission of greenhouse gases and their global warming effects. It will be impossible to achieve the reductions in heat-trapping emissions needed to prevent dangerous levels of global warming. Coal-fired power plants represent the largest source of carbon dioxide (CO_2, the main heat-trapping gas causing climate change). The coal base power plant's emissions must be cut substantially for avoiding the worst consequences of climate change.

Global warming emissions resulting from energy production are environmental problems. Efforts to resolve this include the Kyoto Protocol, which a UN agreement is aiming to reduce harmful climate impacts, which a number of nations have signed.

To limit global temperature to a hypothetical 2 degrees Celsius rise, would demand a 75% decline in carbon emissions in industrial countries by 2050, if the population is 10 billion in 2050. Across 40 years, this averages to a 2% decrease every year. In 2011, the emissions of energy production continued rising regardless of the consensus of the basic problem. Hypothetically, according to Robert Engelman (Worldwatch institute), in order to prevent collapse, human civilization would have to stop increasing emissions within a decade regardless of the economy or population

As quoted in the first para, the earth is the only planet where the life could persist due to its unique and favorable atmospheric conditions. The global warming effects may be a threat to disturb the same. It is therefore necessary that the proper energy-mix is to be followed for generation of power so that energy needs in totality be satisfied for survival of life and its development without disturbing the ecological balance.

In this paper, the various sources for generation of electricity have been studied with their methods of production, merits and demerits taking above points in consideration.

II. FOSSIL FUELS

Fossil fuels are fuels formed by natural processes such as anaerobic decomposition of buried dead organisms. The age of the organisms and their resulting fossil fuels is typically millions of years, and sometimes exceeds 650 million years. Fossil fuels contain high percentages of carbon and include coal, petroleum, and natural gas.

A. Coal:

(i) Preface:

Earlier Coal mining was a very crude process & was an accident prone industry. But it became increasingly important in the phase of industrial revolution when coal was used as a fuel for locomotives, engines etc. As the demand of coal increased, mechanization became inevitable at coal mines & it took place gradually throughout the 1st half of 20th century. By turn of 20th century due to intense use of electricity, the positive impact of mechanization on production and safety was clearly seen. Coal is primarily used as a solid fuel to produce electricity and heat through combustion.

The technical advances are made in all related fields of coal industry including coal winning, transportation, quality control, safety, conservation of coal, communication systems etc. at the mines.

India produced about 578 million tonnes in 2011. When coal is used for electricity generation, it is usually pulverized and then combusted (burned) in a furnace with a boiler. The furnace heat converts boiler water to steam, which is then used to spin turbines which turn generators and create electricity. The thermodynamic efficiency of this process has been improved over time; some older coal-fired power stations have thermal efficiencies in the vicinity of 25%, whereas the newest supercritical and "ultra-supercritical" steam cycle turbines, operating at temperatures over 600 °C and pressures over 27 MPa (over 3900 psi), can practically achieve thermal efficiencies in excess of 45% (LHV basis) using anthracite fuel, or around 43% (LHV basis) even when using lower-grade lignite fuel. Further thermal efficiency improvements are also achievable by improved pre-drying (especially relevant with high-moisture fuel such as lignite or biomass) and cooling technologies.

With the advent of Independence, the country embarked upon 5 year development plan. The need was felt, for increasing coal production efficiently by systematic and scientific development with due consideration to safety of coal industry.

As per the latest estimate of Geological Survey of India (GSI), the coal reserve in India is 211.59 billion tonnes, up to the depth of 1200 metres. Out of this, proven resources are 82.39 billion tonnes. Bihar, Orissa, Madhya Pradesh, West Bengal and Andhra Pradesh account for 96% of the coal resources in the country.

The mission of coal production is set by Coal India Limited, to produce and market the planned quantity of coal and coal products efficiently and economically with due regard to safety, conservation and quality.

(ii) Production:

Method of mining:

(a) Open cast mining:

The most economical method of extraction of coal depends on the depth and quality of the seams, geology and environmental factors. When coal seams are near the surface, coal is extracted by open cast mining. Open cast mines recovers a greater proportion of the coal deposit (90%) as more of the coal seams in the strata is exploited. In Open cast mining, heavy equipment called HEMM (Heavy Earth Moving Machines) are used.

(b) Underground mining:

When coal seams are too deep, the coal is extracted by underground mining. Earlier coal was extracted by very crude ways i.e. manually and it was very unsafe. This method can extract about 40% of coal deposit. Modern underground mining uses remote-controlled equipments including large hydraulic mobile roof-supports which prevent cave-ins until miners & winning (production) equipments have left work area and it can extract about 75% coal deposit.

(iii) Safety:

The poor working condition of labour at some of the private coal mines became the matter of concern for the Government. Prior to nationalization, the private coal mine owners were not giving attention on the safety aspect of mine & workers, resulting in disasters, frequent accidents. The list of historical coal mining disasters is a long one. This was the major reason, that Government has nationalized the coal mines. The coking coal mines were nationalized on 17th Oct'1971 and Non-coking coal mines were nationalized on 31st Jan1973. A safety plays a great role especially at underground mines as it works in adverse mining condition.

Coal mining in deep underground involves a higher safety risk than coal mined in opencast pits. However, modern coal mines have rigorous safety procedures, health and safety standards and worker education and training, which have led to significant improvements in safety levels in both underground and opencast mining.

By constant follow up for safety rules, precautions during work, persuasion and educating the people, the rate of accidents is reduced to a great extent after nationalization. The safety provisions have increased average life expectancy of coal mime working manpower.

Coal is a very effective solid fuel as it burns too easily and produces a great deal of heat which is extensively as fuel used for power generation. However, there are two major concerns over the use of coal: firstly, it is a fossil fuel, so its supplies are finite; and secondly, the levels of carbon dioxide emissions that result from the combustion of coal are believed to be damaging to the environment. However, till proper substitute is found out, coal is the only prime source of energy in India.

(iv) Impact on environment:

Open cast mines deploy heavy earth moving machineries which recover a greater proportion of the coal deposit (About 90%) than underground method as more of the coal seams in the strata remain unexploited. Therefore, the minable coal from open cast mining will be soon exhausted considering the increasing demand & consumption of coal pattern. There is steep production rise by surface / open cast mining but on other hand the surface / land gets completely disturbed. It destroys the genetic soil profile, displaces wild life & habitant, degrades air quality etc.

The future of coal requirement lays in deep underground mining which is coupled with stringent working conditions. It needs to be highly mechanized to achieve the targets coupled with high safety standards. In mechanization and exploitation of coal, there is always possibility of subsidence on surface; dewatering of acidic mine water on surface which destroys / affects agricultural land, flora & fauna. Due to ingress of coal dust while inhaling, the mine workers are prone to diseases like asthma etc. which reduces the average life of workers. The paradigm shift appears to be inevitable, especially in the wake of having to mine from deep to very deep horizons commensurate with fast changing ergonomical challenges in the future ahead.

Today, the coal is important & required to be produced for power generation and its need is increasing till its substitute is not found out. The only solution to this is the provision of proper safety measures at mines which will take care of mankind & nature. With the introduction of appropriate new technologies at coal face, transportation and improved working conditions for manpower, it is seen that accidents in mines have a downward trend due to reduced exposure concentration of workers at active work faces.

As underground mines go deeper & deeper, for safe working & mass production, high capacity & suitable e.g. remote-controlled equipments including large hydraulic mobile roof-supports are inevitable to prevent cave-ins and exposure of workers to adverse working conditions at mines.

Followings are adverse health problems and environmental effects of mining, and coal burning; exist, especially in power stations:

- Air Pollution by Coal-fired power plants may cause lung cancer.
- Generation of hundreds of millions of tons of waste products, including fly ash, bottom ash, and flue-gas desulfurization sludge, that contain mercury, uranium, thorium, arsenic, and other heavy metals
- Acid rain from high sulfur coal
- Interference with groundwater and water table levels due to mining
- Contamination of land and waterways & destruction of homes from fly ash spills
- Impact of water use on flows of rivers & consequential impact on other land uses
- Dust nuisance
- Subsidence above tunnels, sometimes damaging infrastructure
- Uncontrollable coal seam fire which may burn for decades or centuries
- Coal-fired power plants without effective fly ash capture systems are one of the largest sources of human-caused background radiation exposure.
- Coal-fired power plants emit mercury, selenium, and arsenic, which are harmful to human health and the environment.
- Release of carbon dioxide, a greenhouse gas, causes climate change and global warming. Coal is the largest contributor to the human-made increase of CO2 in the atmosphere.
- The underground mining of coal is a dangerous and underground & surface mining are both highly damaging to landscapes, water supplies, and ecosystems.
- Cooling and scrubbing coal plants requires copious volumes of water. Power plants in general are responsible for consumption of freshwater withdrawals, second only to agricultural

In spite of above problems, it is observed that coal would continue to account for more than 50% of the energy mix, with about 70% being used by the power sector. Since coal-based power generation will continue to play a critical role in the coming future, it becomes essential to adopt well-proven technologies like supercritical and ultra-supercritical boilers, instead of using sub-critical technology.

(v) Corrective measures:

A comprehensive and well-defined Environmental Policy has to be adopted to play a proactive role so as to ensure that the mining operations to be carried out in environmentally compatible manner for achieving country's sustainable development and for conservation of nature. Pollution control measures should be taken concurrently with mining operations for maintaining acceptable levels of major parameters of environment i.e. air, water, noise, land and environment. Mining is always recognized as a hazardous industry where ensuring safety is the basic necessity for its sustenance & rapid growth. Therefore, it is essential to improve its safety standards in the mines by the adoption of safer methods of extraction, greater use of safe productive equipments, better supervision and provide proper training to the workmen with safer working habits and also creating safety consciousness amongst them.

B. Oil (Petroleum):

Preface:

Petroleum is a fossil fuel derived from ancient fossilized organic materials. Vast quantities of these remains settled to sea or lake bottoms, mixing with sediments and being buried under anoxic conditions. As further layers settled to the sea or lake bed, remain under intense heat and pressure build up in the lower regions. This process caused the organic matter to change, first into a waxy material known as kerogen, which is found in various oil shales around the world, and then with more heat into liquid and gaseous hydrocarbons via a process known as catagenesis. Formation of petroleum occurs from hydrocarbon pyrolysis in a variety of mainly endothermic reactions at high temperature and/or pressure.

Petroleum, in one form or another, has been used since ancient times, and is now important across society, including in economy, politics and technology. The petroleum industry is involved in the global processes of exploration, extraction, refining, transporting and marketing petroleum products. The largest volume products of the industry are fuel oil and petrol. The rise in importance was due to the invention of the internal combustion engine, the rise in commercial aviation, and the importance of petroleum to industrial organic chemistry, particularly the synthesis of plastics, fertilizers, solvents, adhesives and pesticides.

The growth of oil as the largest fossil fuel was further enabled by steadily dropping prices from 1920 until 1973. After the oil shocks of 1973 and 1979, during which the price of oil increased from 5 to 45US dollars per barrel, there was a shift away from oil; to other resources for electricity generation and then conservation measures increased energy efficiency. It is estimated that between 100 and 135 billion tonnes of oil has been consumed between 1850 and the present.

Production (Extraction):

Production is the operation that brings hydrocarbons to the surface after drilling and prepares them for processing. Oil is often recovered as a water-in-oil emulsion. Oil extraction is the removal of oil from the reservoir (oil pool). The mixture of oil, gas and water from the well is separated on the surface. The water is disposed of and the oil and gas are treated, measured, and tested.

Impact on Environment

Since petroleum is a naturally occurring substance, its presence in the environment need not be the result of human causes such as accidents and routine activities (seismic exploration, drilling, extraction, refining and combustion). Phenomena such as seeps and tar pits are examples of areas that petroleum affects without man's involvement. Regardless of source, petroleum's effects when released into the environment are similar to coal and environmentally damaging.

(a) Ocean / Seawater Acidification

Ocean acidification is the increase in the acidity of the Earth's oceans caused by the uptake of carbon dioxide (CO_2) from the atmosphere. This increase in acidity inhibits life.

(b) Global warming

When petroleum is burned, it releases carbon dioxide; a greenhouse gas. Along with the burning of coal, petroleum combustion is the largest contributor to the increase in atmospheric CO_2. Atmospheric CO_2 has risen steadily since the industrial revolution to current levels of over 390 ppmv, from the 180 – 300 ppmv of the prior 800 thousand years, and it is driving global warming. The unbridled use of petroleum could potentially cause a runaway greenhouse effect on Earth. Use of oil as an energy source has caused Earth's temperature to increase by nearly one degree Celsius. This raise in temperature has reduced the Arctic ice cap to 1,100,000 sq mi (2,800,000 km2), smaller than ever recorded.

(c) Oil spills

Oil spills at sea are generally much more damaging than those on land, since they can spread for hundreds of nautical miles in a thin oil slick which can cover beaches with a thin coating of oil. This kills sea birds, mammals, shellfish and other organisms it coats. Oil spills on land are more readily containable if a makeshift earth dam can be rapidly bulldozed around the spill. The quantity of oil spilled during accidents has ranged from a few hundred tons to several hundred thousand tons. Smaller spills have already proven to have a great impact on ecosystems. oil spills is difficult, requires ad hoc methods, and often a large amount of manpower.

(d) Tarballs

A tarball is a blob of crude oil which has been weathered after floating in the ocean. Tarballs are an aquatic pollutant in most environments, although they can occur naturally. Their concentration and features have been used to assess the extent of oil spills. Their composition can be used to identify their sources of origin, and tarballs themselves may be dispersed over long distances by deep sea currents. They are slowly decomposed by bacteria.

Corrective measures:

The transport sector shares nearly 70% of the total petroleum consumption, the following measures are recommended to reduce the consumption of petroleum products and thereby their import dependency.

- Enhancing the share of public transportation, promoting MRTS (Mass Rapid Transit System), ensuring better connectivity of trains to urban areas of the cities, introducing high capacity buses, and so on. Electrifying the railway tracks to the maximum extent possible. Increasing the share of rail in freight movement by enhancing container movement and providing door-to-door delivery systems.
- Introducing Bharat-III norms across the country for road-based personal vehicles Introducing cleaner fuels such as low sulphur diesel, ethanol blending, and bio-diesel. In the industry sector, given the inefficient diesel consumption by the DG sets for captive power generation, phasing out the use of diesel in industry as well as in the agriculture sector is recommended. Provision of reliable power supply is imperative to achieve this.
- Use of naphtha for fertilizers production and power generation should be avoided to make it available for the petrochemicals sector.
- Natural gas should, therefore, be made available in adequate quantities for off-take by the fertilizer industry and power plants. Natural gas to be the preferred fuel for the country.

The study indicates that natural gas is a preferred option for power generation as well as for the production of nitrogenous fertilizer. The availability of natural gas, therefore, needs to be facilitated by removing infrastructural constraints. Besides its high end-use efficiency, it is a cleaner fuel and relatively much easier to handle than coal. It is, therefore, important to enhance natural gas exploration and production from deep sea.

C. Natural Gas:

(i) Preface:

Natural gas is a fossil fuel formed when layers of buried plants, gases, and animals are exposed to intense heat and pressure over thousands of years. The energy that the plants originally obtained from the sun is stored in the form of chemical bonds in natural gas. Natural gas is a nonrenewable resource because it cannot be replenished on a human time frame. Natural gas is a hydrocarbon gas mixture consisting primarily of methane, but commonly includes varying amounts of other higher alkanes and even a lesser percentage of carbon dioxide, nitrogen, and hydrogen sulfide. Natural gas is an energy source often used for heating, cooking, and electricity generation. It is also used as fuel for vehicles and as a chemical feedstock in the manufacture of plastics and other commercially important organic chemicals.

Natural gas can be "associated" (found in oil fields), or "non-associated" (isolated in natural gas fields), and is also found in coal beds (as coalbed methane). Natural gas is found in deep underground rock formations or associated with other hydrocarbon reservoirs in coal beds and as methane clathrates. Most natural gas was created over time by two mechanisms: biogenic and thermogenic. It is used for Power generation, Domestic use, Transportation, Fertilizers, Aviation, hydrogen. Natural gas is also used in the manufacture of fabrics, glass, steel, plastics, paint, and other products.

As per the Ministry of petroleum, Government of India, India has 1,437 billion cubic metres (50.7×1012 cu ft) of confirmed natural gas reserves as of April 2010. A huge mass of India's natural gas production comes from the western offshore regions, particularly the Mumbai High complex.

(ii) Power generation:

Natural gas is a major source of electricity generation through the use of cogeneration, gas turbines and steam turbines. Natural gas is also well suited for a combined use in association with renewable energy sources such as wind or solar and for alimenting peak-load power stations functioning in tandem with hydroelectric plants. Most grid peaking power plants and some off-grid engine-generators use natural gas. Particularly high efficiencies can be achieved through combining gas turbines with a steam turbine in combined cycle mode. Natural gas burns more cleanly than other hydrocarbon fuels, such as oil and coal, and produces less carbon dioxide per unit of energy released. For an equivalent amount of heat, burning natural gas produces about 30 per cent less carbon dioxide than burning petroleum and about 45 per cent less than burning coal.

(iii) Safety:

Extraction of natural gas (or oil) leads to decrease in pressure in the reservoir. Such decrease in pressure in turn may result in subsidence, sinking of the ground above. Subsidence may affect ecosystems, waterways, sewer and water supply systems, foundations, and so on. Another ecosystem effect results from the noise of the process. This can change the composition of animal life in the area, and have consequences for plants as well in that animals disperse seeds and pollen.

(iv) Impact on Environment:

Natural gas is mainly composed of methane. While the lifetime of atmospheric methane is relatively short when compared to carbon dioxide, it is more efficient at trapping heat in the atmosphere, so that a given quantity of methane has 62 times the global-warming potential of carbon dioxide over a 20-year period, 20 times over a 100-year period and 8 times over a 500-year period.

Coal-fired electric power generation emits around 2,000 pounds of carbon dioxide for every megawatt hour generated, which is almost double the carbon dioxide released by a natural gas-fired electric plant per megawatt hour generated. Combined cycle power generation using natural gas is currently the cleanest available source of power using hydrocarbon fuels, and this technology is widely and increasingly used as natural gas can be obtained at increasingly reasonable costs.

Natural gas produces about 29% and 44% less carbon dioxide per joule delivered than oil and coal respectively, and potentially fewer pollutants than other hydrocarbon fuels. Natural gas produces far lower amounts of sulfur dioxide and nitrous oxides than any other hydrocarbon fuels.

III. Fossil Fuels: Way to a Cleaner, Safer Future

Coal-fired power plants represent the nation's largest source of carbon dioxide (CO2), the main heat-trapping gas. Offshore exploration and extraction of oil disturbs the surrounding marine environment. Natural gas is more potent greenhouse gas than carbon dioxide due to the greater global-warming potential of methane.

Given the critical importance of combating climate change, all coal-related investments and policies should be judged by the ultimate standard of whether they will reduce global warming pollution at the technologies (like Carbon capture and storage) would allow the CO2 from coal-fired power plants to be captured and injected into geologic formations such as depleted oil and gas reservoirs, unmineable coal seams, or saline aquifers. A few measures would require for reducing emission of CO2 as under:

- Increase research and development (R&D) to evaluate the appropriate technologies' potential in the fastest way possible.
- Stop building new coal-fired power plants without such technologies.
- Stop investing in new coal-to-liquid plants and reject policies that support such investments. Such technologies and that the resulting fuel is used to offset coal use rather than natural gas use.
- Significantly increase both deployment of and R&D for energy efficiency and renewable energy.
- Adopt statutes and stronger regulations that will reduce the environmental and societal costs of coal use throughout the fuel cycle.
- Put a price on CO2 emissions by adopting a strong economy-wide cap-and-trade program that, in concert with other policies.

IV. Fossil Fuels: new Technology IGCC & CCS

An alternative approach of using coal for electricity generation with improved efficiency is the integrated gasification combined cycle (IGCC) power plant. Instead of pulverizing the coal and burning it directly as fuel in the steam-generating boiler, the coal can be first gasified to create synthesis gas (Sysgas), which is burnt in a gas turbine to produce electricity (just like natural gas is burned in a turbine). Hot exhaust gases from the turbine are used to raise steam in a heat recovery steam generator which powers a supplemental steam turbine. Thermal efficiencies of current IGCC power plants range from 39-42% (HHV basis) or ~42-45% (LHV basis) for bituminous coal and assuming utilization of mainstream gasification technologies. IGCC power plants outperform conventional pulverized coal-fueled plants in terms of pollutant emissions, and allow for relatively easy carbon capture.

When fossil fuels such as coal, natural gas or oil are burned or processed to produce energy or other petroleum based products, carbon dioxide (CO2) and other pollutants are generated as by-products. Presently, these emissions are released into the atmosphere in the form of GHGs. CCS is a process through which CO2 can be diverted from the atmosphere by capture and storage. CCS is a waste management strategy for carbon dioxide. It does not reduce the production of CO2, but it provides a depository to keep it from harming the environment. The CCS process has three distinct elements. First, the emitted CO2 is captured from industrial utility and compressed either in supercritical form or sub-cooled liquid form for underground storage. The captured CO2 is transported via pipeline or ships to the storage site and injected into deep saline aquifères, depleted oil and gas fields or unmineable coal seams or through an industrial process that permanently fixates the CO2 into inorganic carbonates using chemical reactions or industrial use of CO2 for production of carbon compounds or chemicals. No coal-fired power plants currently employ this technology, but several commercial scale demonstration projects have been announced around the world. It has the potential to substantially reduce CO2 emissions from coal plants, but it also faces many challenges. In its current form the technology would greatly increase the cost of building and running coal plants while greatly reducing their power output.

India is a large coal user and its demand is growing rapidly (IEA 2007). Approximately half of India's current annual CO2 emissions of over 1300 Mt are from large point sources that are suitable for CO2 capture. In fact, the 25 largest emitters contributed around 36% of total national CO2 emissions in 2000; indicating important CCS opportunities (IEA GHG 2008). As a non-Annex I country to the United Nations Climate Change Convention, India has agreed to complete GHG emission. Further, because of the abundance of coal in India, combined with rapidly growing energy demand, the government of India is backing an initiative to develop up to 9 "Ultra-Mega Power Projects." This will add approximately 36 GW of installed coal-fired capacity in India.

V. NUCLEAR POWER

(i) Preface:

Nuclear power, or nuclear energy, is the use of exothermic nuclear processes, to generate useful heat and electricity. The term includes nuclear fission, nuclear decay and nuclear fusion. Presently the nuclear fission of elements in the actinide series of the periodic table produce the vast majority of nuclear energy in the direct service of humankind, with nuclear decay processes, primarily in the form of geothermal energy, and radioisotope thermoelectric generators, in niche uses making up the rest.

(ii) Power Generation:

Nuclear power is the fourth-largest source of electricity in India after thermal, hydroelectric and renewable sources of electricity. As of 2012, India has 20 nuclear reactors in operation in six nuclear power plants, having an installed capacity of 4780 MW and producing a total of 29,664.75 GWh of electricity while seven other reactors are under construction and are expected to generate an additional 6,100 MW.

Nuclear (fission) power stations, excluding the contribution from naval nuclear fission reactors, provides about 5.7% of the world's energy and 13% of the world's electricity in 2012. In India the share of nuclear power is mere 2.27% of the total installed capacity.

(iii) Impact on Environment:

There is an ongoing debate about nuclear power. Proponents, such as the World Nuclear Association, the IAEA and Environmentalists for Nuclear Energy contend that nuclear power is a safe, sustainable energy source that reduces carbon emissions. Opponents, such as Greenpeace International and NIRS, contend that nuclear power poses many threats to people and the environment.

Nuclear power plant accidents include the Chernobyl disaster (1986), Fukushima Daiichi nuclear disaster (2011), and the Three Mile Island accident (1979). There have also been some nuclear submarine accidents. In terms of lives lost per unit of energy generated, analysis has determined that nuclear power has caused fewer fatalities per unit of energy generated than the other major sources of energy generation. Energy production from coal, petroleum, natural gas and hydropower has caused a greater number of fatalities per unit of energy generated due to air pollution and energy accident effects. However, the economic costs of nuclear power accidents is high, and meltdowns can take decades to clean up. The human costs of evacuations of affected populations and lost livelihoods are also significant.

Along with other sustainable energy sources, nuclear power is a low carbon power generation method of producing electricity, with an analysis of the literature on its total life cycle emission intensity finding that it is similar to other renewable sources in a comparison of greenhouse gas(GHG) emissions per unit of energy generated. With this translating into, from the beginning of nuclear power station commercialization in the 1970s, having prevented the emission of approximately 64 gigatonnes of carbon dioxide equivalent(GtCO2-eq) greenhouse gases, gases that would have otherwise resulted from the burning of fossil fuels in thermal power stations.

Since additional nuclear-based capacity displaces coal, it is important to enhance the penetration of this option to the extent possible. Efforts should be directed to step up nuclear capacity to about 70 GW during the modeling time frame, from 2001 to 2031. However, if the modeling time frame is extended beyond 2030, positive impacts of nuclear energy in the form of advanced thorium-based reactors can be realized, with an estimated potential of about 530 GW. One of the big problems with nuclear power is the enormous upfront cost. These reactors are extremely expensive to build. While the returns may be very great, they're also very slow. It can sometimes take decades to recoup initial costs.

(iv) Points to be considered in respect of nuclear power:

Fuel cost:

Fuel costs account for about 28% of a nuclear plant's operating expenses.

Waste disposal cost:

All nuclear plants produce radioactive waste. A heavy cost is involved for storing, transporting and disposing these wastes in a permanent location.

Decommissioning:

At the end of a nuclear plant's lifetime, the plant must be decommissioned. This entails dismantling, safe storage or entombment and requires plants to finish the process within 60 years of closing. Decommissioning a reactor that has undergone a meltdown is inevitably more difficult and expensive.

Safety, security and accidents:

Nuclear safety and security covers the actions taken to prevent nuclear and radiation accidents or to limit their consequences. With the ageing of reactors built in the 1960 and 1970s, there are increased risks of major accidents. This is partly due to design faults but also as a result of radiation causing embrittlement of pressure vessels.

VI. RENEWABLE ENERGY SOURCES

I) Preface:

Renewable energy is generally defined as energy that comes from resources which are naturally replenished on a human timescale such as sunlight, wind, rain, tides, waves and geothermal heat. It provides 21.7% of electricity generation worldwide as of 2013. It is derived from natural processes that are replenished constantly. In its various forms, it derives directly from the sun, or from heat generated deep within the earth. Included in the definition is electricity and heat generated from solar, wind, ocean, hydropower, biomass, geothermal resources, and biofuels and hydrogen derived from renewable resources.

Due to rapid economic expansion, India has one of the world's fastest growing energy markets and is expected to be the second-largest contributor to the increase in global energy demand by 2035, accounting for 18% of the rise in global energy consumption. Given India's growing energy demands and limited domestic fossil fuel reserves, the country has ambitious plans to expand its renewable and nuclear power industries. India has the world's fifth largest wind power market.

Every energy source has its own limitations. Presently, Renewable-energy-based power generation is not a preferred option due to the high upfront costs and low capacity utilization of these technologies. However, renewable energy resources play a crucial role in providing decentralized power to remote areas. Apart from continuing to provide support to renewable energy schemes, efforts are required towards large-scale deployment of related technologies in order to further bring down their costs. In the start, decentralized power generation, especially in remote locations where the grid cannot be extended, should necessarily be based on renewable energy forms to provide these regions with access to clean and reliable energy.

II) Various renewable energy sources:

1. **Wind power**

(i) Preface:

The development of wind power in India began in the 1990s, and has significantly increased in the last few years. India has the fifth largest installed wind power capacity in the world. In 2009-10 India's growth rate was highest among the other top four countries.

(ii) Capacity and site of wind power station:

Airflows can be used to run wind turbines. Modern utility-scale wind turbines range from around 600 kW to 5 MW of rated power, although turbines with rated output of 1.5–3 MW have become the most common for commercial use; the power available from the wind is a function of the cube of the wind speed, so as wind speed increases, power output increases dramatically up to the maximum output for the particular turbine. Areas where winds are stronger and more constant, such as offshore and high altitude sites, are preferred locations for wind farms..

(iii) Installed capacity in India:

As of 31 March 2014 the installed capacity of wind power in India was 21136.3 MW, mainly spread across Tamil Nadu (7253 MW), Gujarat (3,093 MW), Maharashtra (2976 MW), Karnataka (2113 MW), Rajasthan (2355 MW), Madhya Pradesh (386 MW), Andhra Pradesh (435 MW), Kerala (35.1 MW), Orissa (2MW), West Bengal (1.1 MW) and other states (3.20 MW). It is estimated that 6,000 MW of additional wind power capacity will be installed in India by 2014. Wind power accounts for 8.5% of India's total installed power capacity, and it generates 1.6% of the country's power.

2. Hydroelectricity

(i) Preface:

Energy in water can be harnessed and used. Since water is about 800 times denser than air, even a slow flowing stream of water, or moderate sea swell, can yield considerable amounts of energy. There are many forms of water energy:

(ii) Generation of electricity:

In this system of power generation, the potential of the water falling under gravitational force is utilized to rotate a turbine which again is coupled to a Generator, leading to generation of electricity. India is one of the pioneering countries in establishing hydro-electric power plants. The power plants at Darjeeling and Shimsha (Shivanasamudra) were established in 1898 and 1902 respectively and are among the first in Asia.

India is endowed with economically exploitable and viable hydro potential assessed to be about 84,000 MW at 60% load factor. In addition, 6,780 MW in terms of installed capacity from Small, Mini, and Micro Hydel schemes have been assessed. It is the most widely used form of renewable energy. India is blessed with immense amount of hydro-electric potential and ranks 5^{th} in terms of exploitable hydro-potential on global scenario.

The present installed capacity as of 31 May 2014 is approximately 40,661.41 MW which is 16.36% of total electricity generation in India. The public sector has a predominant share of 97% in this sector. National Hydroelectric Power Corporation (NHPC), Northeast Electric Power Company (NEEPCO), Satluj Jal Vidyut Nigam (SJVNL), Tehri Hydro Development Corporation, NTPC-Hydro are a few public sector companies engaged in development of hydroelectric power in India.

Hydroelectric energy is a term usually reserved for large-scale hydroelectric dams. Micro hydro systems are hydroelectric power installations that typically produce up to 100 kW of power. They are often used in water rich areas as a remote-area power supply (RAPS). Run-of-the-river hydroelectricity systems derive kinetic energy from rivers and oceans without the creation of a large reservoir.

3. Solar energy

(i) Preface:

Solar energy, radiant light and heat from the sun, is harnessed using a range of ever-evolving technologies such as solar heating, solar photovoltaic, solar thermal electricity, solar architecture and artificial photosynthesis. Solar technologies are broadly characterized as either passive solar or active solar depending on the way they capture, convert and distribute solar energy. Solar energy an important and relatively inexpensive source of electrical energy where grid power is inconvenient, unreasonably expensive to connect, or simply unavailable. As the cost of solar electricity is falling, solar power is increasingly used even in grid-connected situations as a way to feed low-carbon energy into the grid.

In 2011, the International Energy Agency said that "the development of affordable, inexhaustible and clean solar energy technologies will have huge longer-term benefits. It will increase countries' energy security through reliance on an indigenous, inexhaustible and mostly import-independent resource, enhance sustainability, reduce pollution, lower the costs of mitigating climate change, and keep fossil fuel prices lower than otherwise.

(ii) Installed capacity:

The amount of solar energy produced in India in 2007 was less than 1% of the total energy demand. Government-funded solar energy in India only accounted for approximately 6.4 MW-yr of power as of 2005. However, India is ranked number one in terms of solar energy production per watt installed. 25.1 MW was added in 2010 and 468.3 MW in 2011. By January 2014 the installed grid connected solar power had increased to 2,208.36 MW and India expects to install an additional 10,000 MW by 2017, and a total of 20,000 MW by 2022.

4. Geothermal energy

(i) Preface:

Geothermal energy is from thermal energy generated and stored in the Earth. Thermal energy is the energy that determines the temperature of matter. Earth's geothermal energy originates from the original formation of the planet (20%) and from radioactive decay of minerals (80%). The geothermal gradient, which is the difference in temperature between the core of the planet and its surface, drives a continuous conduction of thermal energy in the form of heat from the core to the surface. The adjective geothermal originates from the Greek roots geo, meaning earth, and thermos, meaning heat.

The heat that is used for geothermal energy can be from deep within the Earth, all the way down to Earth's core – 4,000 miles (6,400 km) down. At the core, temperatures may reach over 9,000 °F (5,000 °C). Heat conducts from the core to surrounding rock. Extremely high temperature and pressure cause some rock to melt, which is commonly known as magma. Magma convects upward since it is lighter than the solid rock. This magma then heats rock and water in the crust, sometimes up to 700 °F (371 °C).

(ii) Generation of Electricity:

Geothermal electricity is electricity generated from geothermal energy. Technologies in use include dry steam power plants, flash steam power plants and binary cycle power plants. Geothermal electricity generation is currently used in 24 countries, while geothermal heating is in use in 70 countries. Estimates of the electricity generating potential of geothermal energy vary from 35 to 2,000 GW. Current worldwide installed capacity is 10,715 megawatts (MW), with the largest capacity in the United States (3,086 MW). Geothermal power is considered to be sustainable because the heat extraction is small compared with the Earth's heat content. The Earth's crust effectively acts as a thick insulating blanket which must be pierced by fluid conduits (of magma, water or other) to release the heat underneath. Electricity generation requires high temperature resources that can only come from deep underground. The heat must be carried to the surface by fluid circulation, either through magma conduits, hot springs, hydrothermal circulation, oil wells, drilled water wells, or a combination of these. This circulation sometimes exists naturally where the crust is thin: magma conduits bring heat close to the surface, and hot springs bring the heat to the surface. If no hot spring is available, a well is drilled into a hot aquifer. Away from tectonic plate boundaries the geothermal gradient is 25–30 °C per kilometer (km) of depth in most of the world, and wells would have to be several kilometers deep to permit electricity generation. The quantity and quality of recoverable resources improves with drilling depth and proximity to tectonic plate boundaries. Estimates of the electricity generating potential of geothermal energy vary from 35 to 2000 GW depending on the scale of investments.

Geothermal power stations are similar to other steam turbine thermal power stations – heat from a fuel source (in geothermal's case, the earth's core) is used to heat water or another working fluid. The working fluid is then used to turn a turbine of a generator, thereby producing electricity. The fluid is then cooled and returned to the heat source.

- ***Dry steam power plants***

Dry steam plants are the simplest and oldest design. They directly use geothermal steam of 150°C or greater to turn turbines.

- ***Flash steam power plants***

Flash steam plants pull deep, high-pressure hot water into lower-pressure tanks and use the resulting flashed steam to drive turbines. They require fluid temperatures of at least 180°C, usually more. This is the most common type of plant in operation today.

(iii) Impact on Environment:

Fluids drawn from the deep earth carry a mixture of gases, notably carbon dioxide (CO_2), hydrogen sulfide (H_2S), methane (CH_4), and ammonia (NH_3). These pollutants contribute to global warming, acid rain, and noxious smells if released.

(iv) Economics

Geothermal power requires no fuel; it is therefore immune to fuel cost fluctuations. However, capital costs tend to be high. Drilling accounts for over half the costs, and exploration of deep resources entails significant risks. A typical well doublet in Nevada can support 4.5 megawatts (MW) of electricity generation and costs about $10 million to drill, with a 20% failure rate. Enhanced geothermal systems tend to be on the high side of these ranges, with capital costs above $4 million per MW and levelized costs above $0.054 per kW·h in 2007. Geothermal power is highly scalable: a small power plant can supply a rural village, though initial capital costs can be high.

India has about 340 hot springs spread over the country. Of this, 62 are distributed along the northwest Himalaya, in the States of Jammu and Kashmir, Himachal Pradesh and Uttarakhand. In a December 2011 report, India identified six most promising geothermal sites for the development of geothermal energy. These are, in decreasing order of potential:

- Tattapani in Chhattisgarh
- Puga in Jammu & Kashmir
- Cambay Graben in Gujarat
- Manikaran in Himachal Pradesh
- Surajkund in Jharkhand
- Chhumathang in Jammu & Kashmir

India plans to set up its first geothermal power plant, with 2–5 MW capacity at Puga in Jammu and Kashmir.

VII. Other Renewable Energy Sources

Biomass

Biomass is biological material derived from living, or recently living organisms. It most often refers to plants or plant-derived materials which are specifically called lignocellulosic biomass. As an energy source, biomass can either be used directly via combustion to produce heat, or indirectly after converting it to various forms of biofuel. Conversion of biomass to biofuel can be achieved by different methods which are broadly classified into: thermal, chemical, and biochemical methods.

Wood remains the largest biomass energy source today; examples include forest residues (such as dead trees, branches and tree stumps), yard clippings, wood chips and even municipal solid waste. In the second sense, biomass includes plant or animal matter that can be converted into fibers or other industrial chemicals, including biofuels. Industrial biomass can be grown from numerous types of plants, including miscanthus, switchgrass, hemp, corn, poplar, willow, sorghum, sugarcane, bamboo, and a variety of tree species, ranging from eucalyptus to oil palm (palm oil). Plant energy is produced by crops specifically grown for use as fuel that offer high biomass output per hectare with low input energy. Some examples of these plants are wheat, which typically yield 7.5–8 tonnes of grain per hectare, and straw, which typically yield 3.5–5 tonnes per hectare in the UK. The grain can be used for liquid transportation fuels while the straw can be burned to produce heat or electricity. Plant biomass can also be degraded from cellulose to glucose through a series of chemical treatments, and the resulting sugar can then be used as a first generation biofuel.

Biomass can be converted to other usable forms of energy like methane gas or transportation fuels like ethanol and biodiesel. Rotting garbage, and agricultural and human waste, all release methane gas – also called "landfill gas" or "biogas". Crops, such as corn and sugar cane, can be fermented to produce the transportation fuel, ethanol. Biodiesel, another transportation fuel, can be produced from left-over food products like vegetable oils and animal fats. Also, biomass to liquids (BTLs) and cellulosic ethanol are still under research.

The biomass used for electricity generation varies by region. Forest by-products, such as wood residues, are common in the United States. Agricultural waste is common in Mauritius (sugar cane residue) and Southeast Asia (rice husks). Animal husbandry residues, such as poultry litter, are common in the UK.

Biofuels, Bioethanol, Biodiesel

Biofuels include a wide range of fuels which are derived from biomass. The term covers solid biofuels, liquid biofuels, and gaseous biofuels. Liquid biofuels include bioalcohols, such as bioethanol, and oils, such as biodiesel. Gaseous biofuels include biogas, landfill gas and synthetic gas.

Bioethanol is an alcohol made by fermenting the sugar components of plant materials and it is made mostly from sugar and starch crops. These include maize, sugar cane and, more recently, sweet sorghum.

With advanced technology being developed, cellulosic biomass, such as trees and grasses, are also used as feed stocks for ethanol production. Ethanol can be used as a fuel for vehicles in its pure form, but it is usually used as a gasoline additive to increase octane and improve vehicle emissions. Bioethanol is widely used in the USA and in Brazil. The energy costs for producing bio-ethanol are almost equal to, the energy yields from bio-ethanol. However, according to the European Environment Agency, biofuels do not address global warming concerns.

Biodiesel is made from vegetable oils, animal fats or recycled greases. Biodiesel can be used as a fuel for vehicles in its pure form, but it is usually used as a diesel additive to reduce levels of particulates, carbon monoxide, and hydrocarbons from diesel-powered vehicles. Biofuels provided 2.7% of the world's transport fuel in 2010.

***Wave power*, *tidal power*:**

Wave power, that captures the energy of ocean surface waves, and **tidal power,** converting the energy of tides, are two forms of hydropower with future potential, however, not yet widely employed commercially. The ocean thermal energy conversion, that uses the temperature difference between cooler deep and warmer surface waters, has currently no economic feasibility.

VIII. Evaluation of Energy Sources

Looking into the merits and demerits of power generating sources i.e fossil fuels, nuclear and renewable energy sources etc as enumerated above, following facts have to be looked into:

- The cost of climate change through emissions of greenhouse gases is hard to estimate. Carbon capture and storage may become mandatory.
- The cost of environmental damage caused by (fossil or renewable) energy sources, both through land use (whether for mining or fuels for power generation) and through air and water pollution and solid waste.
- The cost and political feasibility of disposal of the waste from reprocessed spent nuclear fuel is still not fully resolved.
- Operating reserve requirements are different for different generation methods. On the other hand, many renewable are intermittent power sources and may shut down together if they depend on weather conditions, so the grid will require either back-up generation capability or large-scale storage if the portion of generation from these renewable is significant. (Some renewable such as hydroelectricity have a storage reservoir and can be used as reliable back-up power for other power sources.)
- New nuclear power plants are designed for a minimum of 60 years, and may be able to be refurbished. Likewise, the waste from reprocessed fuel remains dangerous for about this period, however reprocessing/reuse of spent nuclear fuel can add future value as well.
- Due to the dominant role of initial construction cost and the multi-year construction time and planned lifetime, the interest rate for the capital required is of particularly high importance for estimating the total cost.
- Since coal-based power generation will continue to play a critical role in near future, it is essential to adopt well-proven technologies like supercritical and ultra-supercritical boilers.
- It is important to accelerate the transition to other efficient coal-based power generation technologies such as the CCS and IGCC technology.
- In viewpoint of energy security and the need to reduce its dependence on imports of all the conventional energy fuels, the country needs to undertake all possible options, on the demand and supply side simultaneously to reduce its total energy requirements as well as diversify its fuel resource mix and using cleaner, renewable energy sources.

IX. Conclusion

Although most people are aware of the environmental concerns associated with conventional energy production, they do not connect their own personal energy consumption having a significant impact on global environment. The only way to improve the global impact of conventional energy production is through individual awareness regarding energy conservation and the advantages of renewable energy sources over the conventional energy sources. Till a suitable source is not found out, the conventional resources have to be utilized judiciously and economically for better future.

Many nations are integrating renewable energy into their utilities. Since 1994, the Japanese have used subsidies to install rooftop PV panels on 33,000 homes and plans to install PV on 70,000 roofs, providing 4,600 MW of solar energy. Germany has set a goal of 300 MW of solar energy and has over 6,000 MW of wind power, working towards a goal of 22,000 MW. Several states have already created legislation to insure the development of renewables in the free market climate of deregulation and some are in the process of legislating Renewable Portfolio Standards. It is to be insured that renewables continue to be developed under a deregulated market where normal market activities may not provide the incentives for capital investments in renewables. A Renewables Portfolio Standard may mandate that a percentage of energy that a utility provider supplies be renewable, or that a percent of profits go to the support of research, development, or infrastructure of renewables. These standards are often implemented on a step-wise increment of percent supplied or support of renewables industries. There has recently been a push for such portfolio standards to be implemented on a national level.

To overcome the obstacles of high capital costs in creating renewable power sources and to counter the tendency of consumers to choose the cheapest product various ways should be found out. Initially, the funds may be generated by placing a small tariff on all utilities bills in the state. This money be utilised toward systems upgrades, construction of renewable energy generators, consumer education, or renewable generation credits which can be used to support renewables in other areas of the country.

Other incentives that have to be developed including generation disclosure, net metering, and green pricing. Generation disclosure mandates that information pertaining to the emissions (CO2, NOX, SOX, mercury) of a given utility be disclosed to potential customers. Net metering allows consumers to install renewable generation systems in their homes and get credit with their utility for energy they contribute to the grid. Green pricing programs allow utilities to buy energy from a renewable generator, and allow customers a share of this energy at a premium price.

The energy bill should also include information about the emissions caused by the individual's energy consumption. It is important for customers to understand the individual impact their energy consumption has on the environment. Under the information about the amount of energy consumed in the month, the bill should state how much carbon, sulfur, nitrogen, and mercury emissions resulted from this consumption. Individuals may not understand why these emissions are bad for the health of society or the environment. To clarify this, customers should also receive a Sustainable Energy Information Brochure that lists the environmental and health effects of these emissions.

Above points for energy conservations would enlighten the individuals, concerned and appropriate actions would be taken which will not only beneficial to them alone but also for society, country and world as a whole in present situation and also in coming future.

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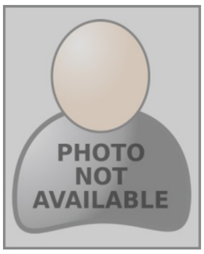

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