The Flip Side of Renewable Energy-A Critical Review

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Abstract: The ever-increasing world energy demand cannot be satisfied with fossil fuels; because conventional energy sources are finite, and they are exhaustible. Alternatives are required to stop climate collapse and wars for natural resources. Solving the energy crisis is challenging for scientists and engineers. Clean and inexhaustible renewable energy sources like solar, wind, geothermal, biomass, fuel cell,orhydro energy are the sources of alternativeenergy.However, there are a few issues associated with each of the renewable energy sources. Jumping into such alternatives without being aware of their inherent problems may cause serious concerns in the future. The present review compiles the problems associated with renewable energies and their possible solutions and directions of research.

Keywords: ***renewable energy; disadvantages; hydrogen power; biogas; wind energy; solar energy; geothermal energy.***

1.0 INTRODUCTION

Any activity in this world, by human beings or by nature, is driven by energy in any form. In developing countries, the energy sector is very important because of the ever-increasing energy demands requiring huge investments. (https://prog.lmu.edu.ng/colleges_CMS/document/books/MCE%20432%20Module%201.pdf). Renewable energy is a type of clean energy that is collected from renewable coffers that are naturally replenished within a mortal timescale. It includes solar, wind, hydro, tides, and geothermal heat sources (Lenton et al, 2019).In Figure-1,some of the renewable energy sources are indicated. With the rapid development of the global population and economy, energy demand will increase exponentially, which the fossil fuel reserve cannot cater to. Moreover, the consumption of fossil fuelsleads to environmental pollution and global warming (Zou et al., 2016). Renewable energy will play an important role in solving global warming problems. Thus, the energy structure should gradually transform and upgrade to control global warming below 2 °C (Lenton et al., 2019).

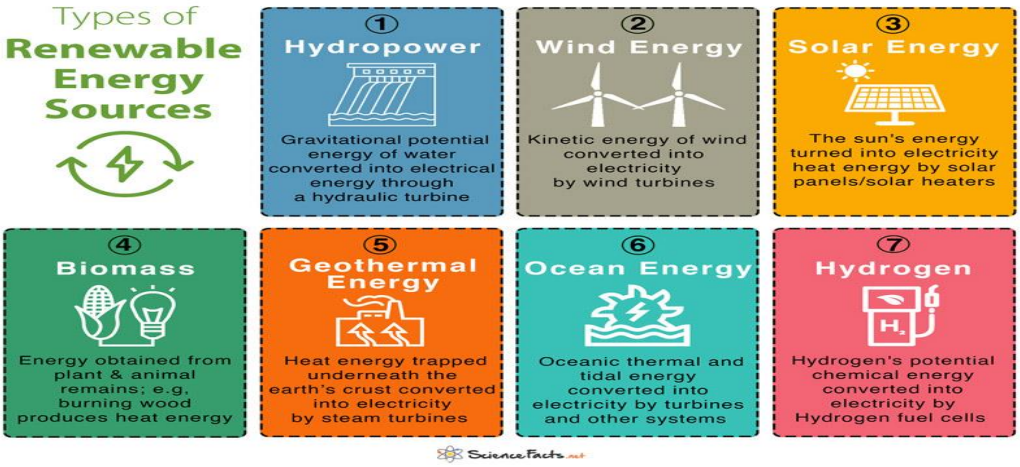

Fig-1: Types of renewable energy (Science Fact, 2022)

Some advantages of renewable energy resources are as follows: -

- Zero carbon emission.
- No or low emission of greenhouse gases. Fig-2 shows the comparative emission of greenhouse gases.
- No or low emission of air pollutants.
- Low costs.
- Creates jobs.
- Resilient energy system.
- Accessible to all, hence democratic.

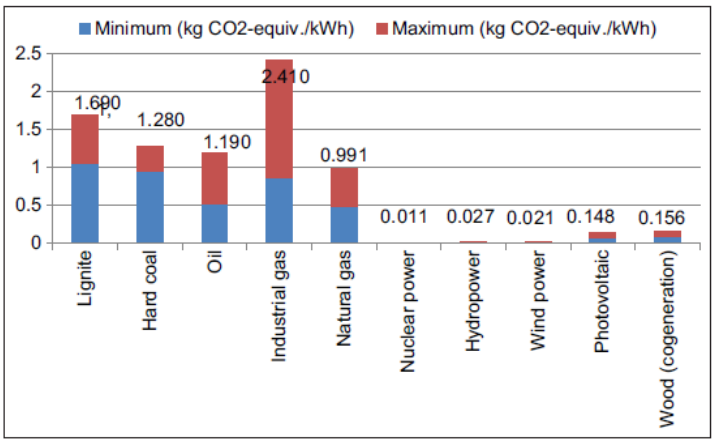

Fig-2: Comparison of CO_2 emission of renewable and non-renewable energy resources (Maradin et al, 2021)

The renewable energy report of the United Nations Environmental Programme shows that the total global installed renewable power capacity in 2021 is about 3146 GW and the world targets net zero emission by 2050. In 2021, 28.3% of global electricity was generated by renewable sources. But the increased energy demand is still being catered with fossil fuels. In India, as of December 2021, the total installed capacity of renewable energy is 151.4 GW, and India is targeting 500GW of it by 2030 whereas a net zero emission is envisaged in 2070.

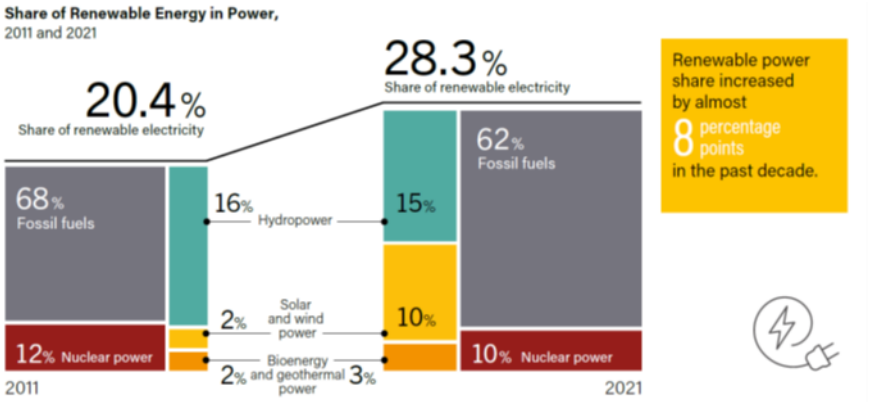

Fig-3: Global Electricity production, and share of Renewable (UNEP, 2022)

However, the materials and technology of all the renewable energy sources have some problems associated with them. Before switching over to renewable energy sources, people must be aware of the flip sides of the same so that they can be taken care of during the implementation. Research should continue to overcome the issues. In the following sections, the disadvantages and their possible solutions will be discussed for each of the renewable energy sources.

2.0. Problems and possible solutions of various renewable energy sources

2.1. Solar Energy

The most familiar alternative to fossil fuels is solar energy. The amount of solar energy that falls on the Earth's surface is more than 200 times the total annual commercial energy currently utilized by the entire human population(Verghese, 1998). Especially in tropical countries like India, solar energy can be an economical alternative to fossil fuels. Solar energy technology is classified into two types:
1. Passive solar (direct and indirect use of the heat from the sun)
2. Active solar (using electromagnetic radiation of sun-solar photovoltaics or PV).
Solar energy can be exploited in three ways- solar thermal power plants, solar thermal systems and solar photovoltaics.

Fig-4(a) Solar panel array (Wikimedia Commons,2022)

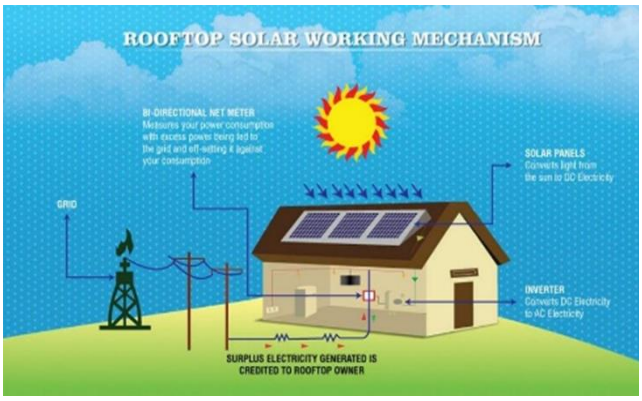

Fig-4(b):Working Mechanism for Solar energy (Alrikabi, 2014)

The total global capacity of solar PV is about 942GW though recently the cost of the photovoltaic module has increased by 57% due to an increase in the cost of raw materials (UNEP, 2022). In India, the capacity of solar power is about 49.3 GW as of December 2021(MNRE, 2022). However, the relative costing of different sources of energy is a complicated calculation that involves interdisciplinary participation and includes various social and environmental costs as well. Government policies also contribute to the cost.

Though solar panels do not emit greenhouse gases, they have some adverse effects on the economy and environment. The major problem is the capital cost of a solar power plant. Production, construction, maintenance, transportation, and decommissioning of solar panels involve theuse of toxic chemicals; these chemicals can release greenhouse gases including fluorides, SO_x, or NO_x. During the production of panels from silicon, workers are exposed to silicon that may cause silicosis in them. Solar PV required about 26 gallons of water to generate each MWh of power. Electricity is consumed for the manufacturing process of solar panels. The panels generally require large land or rooftop area. Sometimes trees are cut to get plain land and uninterrupted access to sunlight on the panels. This alters the land use pattern and the ecosystem is affected. Soil erosion and alteration of drainage patterns may also be caused (Vezmar et al, 2014).

The use of recycled water, the invention of an energy-efficient manufacturing process, and installation on the rooftops, canal tops, agrovoltaic, floating solar are some of the possible remedial measures. A plan of disposal of the panels should be made at the end of their lifespan of 25-30 years. EU advised the manufacturers to include the cost of recycling into the cost of the panels and disposal should be made in a specialized secured landfill facility. After extracting the valuable metals from the used

panels, the scrap silicon and plastics may be incinerated with cement. (Prendergast, 2020). Barren lands may be used for installing the solar panels. Use of Building Integrated Photovoltaic (BIPV) at facades of the buildings may reduce the space-demand. However, architectural integration and customization are required before using BIPV widely (Attoye et al 2017). Continued research and developments are going on regarding such retrofitting and installation which are making the technology economically viable.

2.2. Wind Energy

Wind Energy, generated by air, is an alternative to fossil energy. The location of wind turbines is an important factor, which highly influences the performance of the turbine. Wind first hits a turbine's blades that are connected to a turbine, causing them to rotate. So, the kinetic energy is converted into rotational energy, thenit is connected to a generator to produce electrical energy. Wind energy produces no air or water pollution, involves no toxic or hazardous substances, and poses no threat to public safety and the environment (Verghese, 1998).The total installed capacity of wind energy all over the world is about 102GW (UNEP, 2022) whereas in India, as of December 2021, the wind energy acquired is about 40GW(MNRE, 2022).

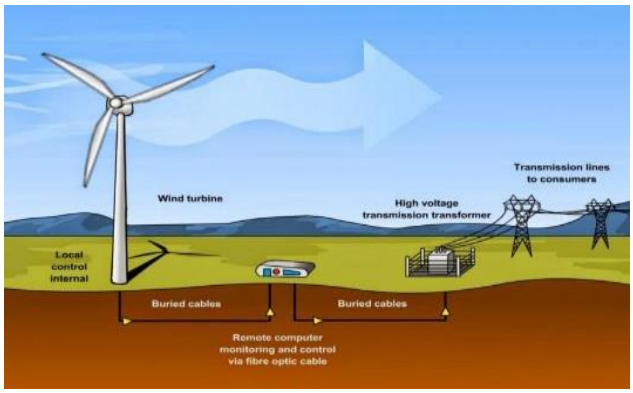

Fig-5: Wind Energy working mechanism-schematic diagram (Alrikabi, 2014).

However, like a solar power plant, windmills also need a huge quantity of land that may change the land use pattern and adversely affect agriculture. Sometimes installation of windmills needs the cutting of trees; hence destroying biodiversity and wildlife. Turbine blades may cause injury and change the migration pattern of birds and animals. The noise of a running turbine may influence the surrounding ecosystem. Turbine blades are very large; they are made of steel, aluminum or polymeric composite materials. While metals were relatively easy to recycle, polymers are not. Waste blades, if sent to landfill, would cause a scarcity of land. Fuels and lubes for the maintenance of turbines also pose pollution to the surrounding land.

The technology of windmills should improve to take care of the noise issue; a lightweight, sturdy and easily recyclable material should be developed for turbines. The efficiency of the turbine blades should be enhanced considering local meteorological conditions(WaPT, 2022).The selection of land for the installation of windmills is a critical issue – desert or a coastal area, where the lands are barren, may be suitable and that can eliminate many disadvantages(Vezmar et al, 2014). Bladeless wind turbines (BWT) are based on vortex induced vibration and can eliminate most of the blade-related disadvantages of a windmill. Offshore wind farms are advised to minimize land requirement. But the influence of offshore wind mills on the marine environment is yet to be explored completely,

especially in India. Again, this is an interdisciplinary area involving environmental, marine and atmospheric scientists.

2.3. Biogas and Biomass Energy

Biomass is a renewable organic resource that originated from the life processes of plants and animals. It contains stored chemical energy that should be converted into power or fuel. Various types of biomasses are given in Figure – 6. Biomass can be converted into energy in the following ways:

- Direct combustion to generate heat.
- Thermo chemical conversion to solid liquid and gaseous fuels – by pyrolysis, incineration, and gasification, depending on the quantity of oxygen used.
- Chemical conversion - catalytic processes like trans-esterification of vegetable oil to produce biodiesel.
- Biological conversion –biological processes like fermentation to form biofuel - ethanol or renewable natural gas.(EIA, 2022)

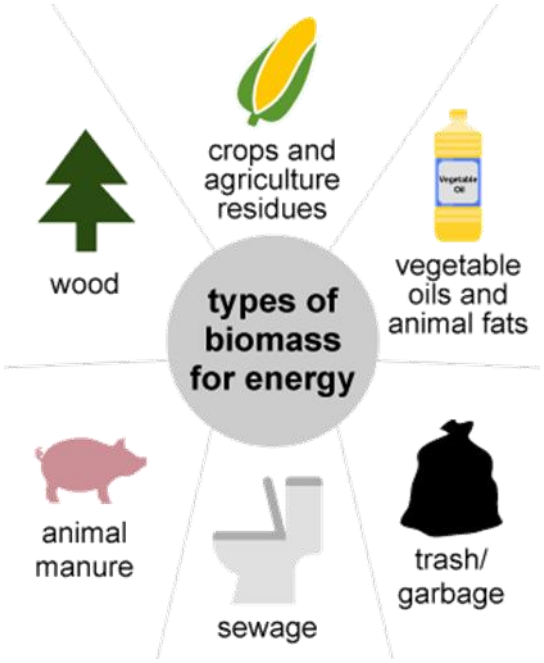

Fig-6: Types of biomasses for energy (EIA, 2022)

In 2020, the global capacity of modern bio-energy for heating was 14.7 EJ (1EJ=10^{18}Joules); it was 7.6% of the global heating requirement. Biofuels like ethanol and biodiesel contributed around 3.5% of the energy required in the transport sector (UNEP, 2021). In India, formal bioenergy production was 10.6GW at the end of 2021(MNRE, 2022); however, the actual quantity may be much more in the informal sector.

It is an environment-friendly approach to use biomass for the generation of energy instead of fossil fuels. However, good management practice is necessary to overcome the associated disadvantages. Except for the type of fuel, power plants using biomass are based on the same principle as those with conventional fuels. Hence the pollutants like toxic gases and particulate matter, emitted out of a biomass power plant, should also be efficiently managed. For biofuels, a large amount of agricultural land is required to produce raw materials like corn or oilseeds. This may interfere with the countries'

agriculture and food production-distribution system. Biogas production is a water-intensive process, it may pose water stress (Vezmar et al, 2014).

Proper emission control from the bio-fuel-driven power plant as well as regular maintenance and treatment of effluents from biogas plants may reduce some of the environmental concerns including foul odor and scum formation. The use of agricultural wastes rather than food grains for the production of bio-ethanol may save from the possible potential food stress. This may also prevent deforestation that might have been done for feed crop production. Burning agricultural residue is a major source of air pollution; using agricultural waste as biomass can reduce such problem and states like Uttar Pradesh, Punjab have already taken initiatives in line of this.

2.4. Fuel Cell

The fuel cell converts the chemical energy of hydrogen to power by its direct combination with oxygen to produce water. In the anode chamber, hydrogen is split into proton and electron. The electron travels through the external circuit to generate an electric current; the proton passes through the membrane and combines with oxygen to form water. Figure-7 shows the working principle of a fuel cell.

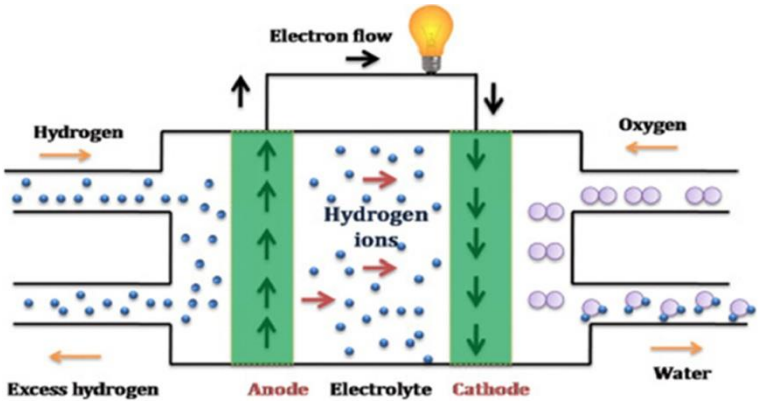

Fig-7: Schematics of the working principle of a hydrogen fuel cell(Zakaria et al., 2021)

A major concern for a fuel cell is the supply of hydrogen that is generally produced by the electrolysis of water; the power used for electrolysis is generally conventional. India targets 5 million tons ofgreen hydrogen per year by 2030. Another disadvantage is its huge initial capital cost. Research and development are going on and should continue to explore alternative materials for costly electrodes without compromising energy output.

2.5. Hydroelectricity

Large and small hydroelectric or hydel power plants convert the potential and kinetic energy of the flowing water into electricity. It has a dam for the storage of water and when released, the flow of water rotates the turbine to generate electricity (Fig-8a and b). Since no greenhouse gas is emitted, the power is green; at the same time, water is also a renewable resource. The total installed capacity of hydropower is around 1197GW. But due to changes in hydrological conditions for climate change, it is decreased by 3.5% in 2021 (UNEP, 2022). At the end of 2021, hydropower in India was 51GW (Usman, 2020).

Hydropower is 2000 years old history. Greeks used the power of flowing water for grinding wheat to produce flour; in mid-1700, a French military engineer, Belidor, introduced the ancestor of the modern hydropower-driven turbine. The first hydro power station in the world was in US in 1881 and in in 1897 in India. The cost of hydropower is low, compared with the cost of conventional energy. But there are environmental and socio-economic disadvantages associated with hydroelectricity.
A huge quantity of land is required for the construction of a hydroelectric plant. Human settlements are destroyed and a huge number of environmental refugees impose stress on the country's economy. Complete rehabilitation is never possible and many farmers have to change their professions. The natural flow of the river is inhibited, disturbing the ecosystem. Silting is a major problem in the reservoir and the flood gates. During construction, air, noise, and other pollution are experienced. Any natural calamity like drought or earthquake and man-made disasters like war or terrorism may destroy a hydroelectric plant.

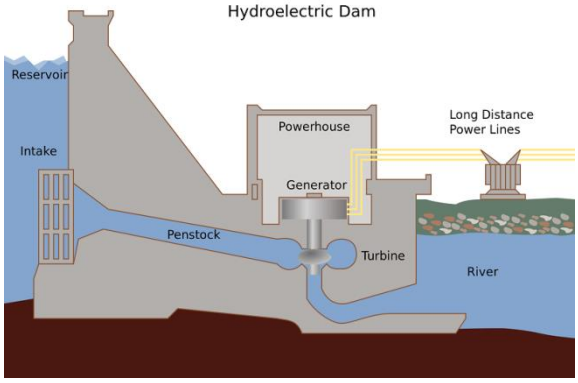

Fig-8(a) Schematic of a hydel power plant (Hanania et al, 2021)

Fig-8(b) Photograph of a hydropower project (*CLIMATE HOME NEWS*, 2013)

According to some studies (Kishore et al., 2021), most of the problems associated with hydel power may be solved by installing small (less than 25MW) or micro (less than 100kW) hydropower units rather than large ones. These plants are less intrusive towards human settlements and the local ecosystem. Run of the river (ROR) power plants with no or little storage of water may also be considered for intermittent power supply in an environmentally sustainable manner. However, all such proposals have their own advantages and disadvantages that should be judiciously considered.

2.6. Tidal power

Though not commercially viable and not a single tidal power plant has been installed in India, tides are another renewable source of power. Tides are vertical rise and fall of the sea level mainly due to the attraction of the celestial bodies. Tidal barrage, tidal fence and small devices are generally used to extract the kinetic energy of the moving water. The installations are expensive and can badly affect the marine ecosystem (Vikas et al 2016).

2.7. Geothermal power

Geothermal energy is the heat within the earth that can be extracted for power. The origin of this heating is the heat of the formation of the Earth, from radioactive decay of minerals within the Earth's core and solar energy. The temperature at the Earth's core is about 5000◦C. Generally, the average

temperature gradient within the first 100 km from the Earth's surface is somewhere around 15–30◦C/km. Figure-9(a) shows the temperature profile of the earth at various levels below the crust (Ejiga et al., 2022). This temperature gradient can result in a continuous flow of heat energy that can be accomplished by a suitable fluid, mostly water. Figure 9(b) shows the schematic of a geothermal power plant.

It is stable and green energy, needing no fossil fuel. It does not vary seasonally like solar or wind energy. In 2021, the global total geothermal energy capacity was about 15 GW(UNEP, 2022). India is yet to install its first geothermal energy plant.

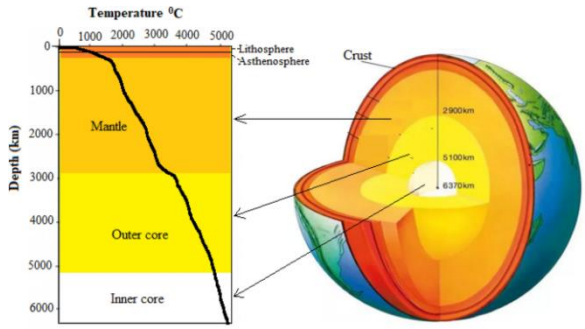

Fig-9 (a)Temperature profile up to the core of Earth (Ejiga et al., 2022)

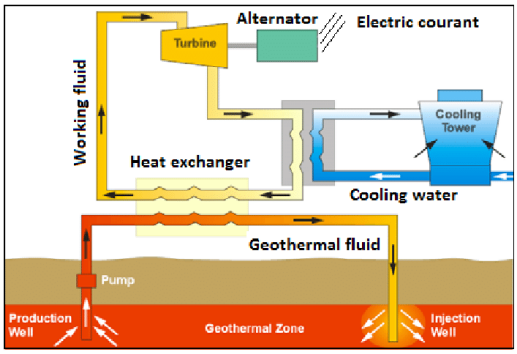

Fig-9 (b) Schematic diagram of a geothermal powerplant(Cousins and Larkin, 1984)

The major disadvantage of a geothermal plant is its high capital cost to drill down the Earth's crust. The other problems are disturbances caused to the tectonic plates leading to earthquakesor the discharge of toxic gases from the Earth's sub-surface. All the places are not suitable for the extraction of geothermal energy-so it is location-specific. The extraction of geothermal heat is water-intensive; a huge quantity of hot water and steam is lost (Igwe2021, Pros and Cons of geothermal energy, 2022). The remedy may be the research to develop a low-cost technique that would not disturb the sub-surface geological state. Research should also continue for exploring heating fluids and their proper management. Pollution control measures should be taken to emanate pollution due to toxic gases from the ground.

3.0. Conclusion

This review summarizes the basic principles of various renewable energy acquisitions, their advantages, disadvantages, and possible remedies to overcome the issues. Due to the scarcity of conventional energy sources and their adverse impacts on the environment, human civilization is trying to switch over to renewable energy sources for their energy needs. Before implementing non-conventional energy technologies, humankind should be aware and should try to eliminate the negative points for better efficiency and utilization. Thus, SDG-7 (affordable and clean energy-7th goal for sustainable development) can be achieved.

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