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RESEARCH ARTICLE

A REVIEW ON DEVELOPMENT OF RENEWABLE ENERGY SOURCES IN INDIA

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Abstract

the twin issues arising from exploitative interaction of humans with natural resources. Excessive utilization of coal and oil for energy generation lead to the multiple environmental problems. In the current scenario the global energy needs can only fulfill by adopting non conventional sources of energy. The present review deals with efforts and achievements of India to develop sustainable, efficient and cleaner energy resources not only in urban but also in rural areas. India has always shown its willingness in leadership to fight climate change. Presently, India is world's third renewable energy producer with 40% of energy capacity installed in the year 2022 (160 GW of 400 GW) coming from renewable sources. Ernst & Young's (EY) 2021 Renewable Energy Country Attractiveness index (RECAI) ranked India third behind USA and China. In November 2021, India had a renewable energy capacity of 150 GW consisting of solar (48.55 GW), wind (43.03 GW) hydro power (51.34 GW) and Biomass (10.62 GE). India has committed for a goal of 500 GW renewable energy capacity by 2030. The country's vision is to achieve Net Zero Emissions by 2070.

Energy generation and
environmental conservation are

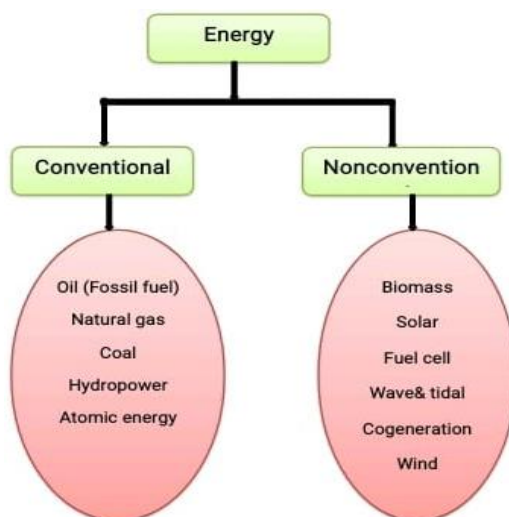
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Introduction:-

Energy has been a crucial factor in the current model of development. There is a close relationship between energy consumption and economic growth as measured in terms of the growth of Gross Domestic Product (GDP) in any country. It is now argued that the cost and availability of energy are two major factors in promoting economic growth of society or country as a whole. However, as the energy intensive industrial economies have expanded, their adverse impact on the environment has grown. This aspect has come under closer scrutiny in the past few decades and an understanding of the role of energy in economic development will help us develop models of eco-friendly energy usage. Therefore, we begin our discussion of the energy as resource with an understanding of the multi-faceted role of energy in economic development. We will examine the energy resource base at our disposal and the various energy options available to us. Finally, we will analyse the carrying capacity of the Earth in relation to our energy demand with a view of switching over to renewable energy sources [1].

The demand for energy doubles every 14 years and is taken as one of the indicators of development of a country. India, with 16% of the world's population consumes roughly 3% of the total energy produced in the world, in comparison of USA which has 6.25% of the world's population and utilizes 30% of the energy produced. Despite continuous increase in energy use, per capita consumption in India is still very low compared with other countries. Even today, about 80% of

our population continues to depend on fuel wood, dung and agricultural wastes [2]. We know that non-renewable sources of energy such as fossil fuels, coal and petroleum, are not going to last for long. Forests are also being depleted at the alarming rate due to indiscriminate felling of trees. It has become, therefore, necessary to think of alternative, non conventional sources of energy [3]. Energy needs in India are met by harnessing two categories of energy sources as shown below.



1. Conventional Sources:

The power production through conventional sources like oil, gas, coal and hydro energy far behind the current demand driven by growth in agriculture industry and the population. India's electricity sector currently faces problems of capacity, distribution losses, poor reliability, and frequent black outs. Indian industry cites power supply as one of the biggest limitations on progress. One government estimate projects 8-10% annual growth in energy demand over the next 15 years if the economy grows as expected in the 7-8% per year range. The short fall implies greater dependence on international markets.

1.1. Oil (Fossil Fuel):

Oil supplies nearly 30% of India's energy. Oil consumption in the country was approximately 1.93 million barrels per day (bpd) in 1999 and was about 4.7 million bpd in 2017. In 2017, India imported about 198 million tonnes of crude oil and its products. India draws most of its imports of oil from the Bombay High, Upper Assam, Cambay, Krishna-Godavari, and Cauvery basins. Oil reserves are estimated at 4.7 billion barrels. The Bombay High Field, India's largest producing field, generated 250,000 b/d in 1998 and 210,000 b/d in 1999. Consumption of petroleum products rose from 57 million tonnes in 1991-1992 to 196 million tonnes in 2016. The India Hydrocarbon Vision 2025 report estimates future refinery demand at 368 million tons by 2025. Thus, India is becoming a major global market for petroleum products [1,4].

1.2. Natural Gas: About 7% of India's energy needs are met by natural gas especially in power generation, fertilizers, and petrochemicals production. Natural gas can serve to reduce dependence on foreign oil. Absence of sulphur dioxide and reduced levels of carbon dioxide and nitrogen oxide are major environmental benefits of using natural gas. Currently, India's natural gas consumption is 50 billion cubic meters (bcm) and is mostly met by domestic production. In 2017, India imported 27,570 million cubic meters of natural gas [5].

1.3. Coal (Fossil Fuel):

India depends on coal for more than half of its total energy needs. Nearly three quarters of the country's electricity and 63% of commercial energy comes from coal. India has huge coal reserves accounting for 8% of the world's total. It is the third leading coal producer in the world after China and the United States. Most of its coal demand is satisfied through domestic production with the only exception being coking coal that is in short supply. Despite India's wealth in coal reserves, only about 3% is coking coal so India's steel industry must import coking coal to meet about 25% of its annual needs [6].

1.4. Hydro power:

Hydro power is the cheapest, and cleanest and, hence, regarded the best source of energy. However, obtaining electricity from mega dams has given rise to many controversies in recent times and small hydro power plants are emerging as viable alternatives. These plants serve the energy needs of remote and rural areas where the grid supplies not available [7].

1.5. Atomic Energy:

The energy released by splitting of atom in a controlled manner can be utilized for generation of electricity. The device used for this purpose is called an atomic reactor. Nuclear reactors produce heat, which is used to generate steam, for rotating turbines for generating electricity. It is estimated that 1 kg of natural uranium, written as ^{235}U , generates energy equal to that produced by 35,000 kg of coal. Energy production from nuclear fuels like uranium is relatively clean, efficient, and can serve as a substitute for coal and petroleum. However, nuclear reactors need to be situated at places far away from human habitation [8].

2. Non-Conventional Sources:

There are various non-conventional sources of energy as given below:

2.1. Biomass Energy:

This is a renewable energy source derived from plant resources, animal waste and the waste of various human activities. It is also derived from the by-products of the timber industry, agricultural crops, raw material from the forest, major parts of household wastes and wood. Biomass is an important source of energy and the most important fuel worldwide after coal, oil and natural gas. Biomass does not add net carbon dioxide to the atmosphere as it absorbs the same amount of carbon in growing as it releases when consumed as fuel. Its advantage is that it can be used to generate electricity with the same equipment or power plants that are now burning fossil fuels. Biomass fuels used in India account for about one third of the total fuel used in the country. Over 90% of the rural households and about 15% of the urban households use biomass fuels (e.g. wood, cow dung cakes, crop residues and sawdust). The inefficient burning of such fuels in traditional chulhas is causing a serious problem of indoor air pollution and consequent health hazards. Moreover, the unsustainable level of consumption of fuel wood leads to deforestation and desertification, which degrades the environment. Thus proper management of biomass as a resource is very essential. In this context, technological solutions, institutional arrangements, financial support and training schemes for ensuring adequate and affordable clean energy systems and services using biomass assume great significance [9].

An initiative in this direction has come from the Ministry of Non-conventional Energy Sources (MNES). It has been promoting indigenously developed technologies for efficient utilization of biomass fuels with a focus on extraction of more energy, reduction of household consumption of firewood, generation of employment and improvement in the living standards of rural population.

Biomass gasifier is another technology in use for energy generation. A biomass gasifier converts solid biomass, both woody and powdery, materials such as wood, agricultural and agro-industrial wastes into gas through thermo chemical gasification process. Gasifier converts solid fuel into a more convenient-to-use gaseous form of fuel. As much as 1890 Kcal of heat can be produced from half a kilo of dry plant tissue. This is equivalent to the heat available from 250g coal. It has been found to be more practical to compress biomass into briquettes (small hard blocks of different shapes used as fuel) and thereby improve its utility and convenience of use. In the dense briquetted form, biomass can either be used directly as fuel instead of coal in the traditional chulhas and furnaces or in the gasifier [10].

2.2. Solar Energy:

Solar energy is the most readily available abundant source of energy. It is free as it does not belong to anybody. It is also non-polluting. The energy we get today from the fossil fuels like coal is in reality sun's energy, trapped in plants millions of years ago. Plants make their food and grow by using solar energy for photosynthesis. Millions of years ago, huge forests got buried in the earth's crust and they got transformed into coal and oil under great pressure and temperature therefore coal and oil are called fossil fuels. Nowadays, we have learnt to harness solar energy for various purposes. Solar energy can be used directly to give us hot water during winter, or run a refrigerator. It can be used, for room heating in colder regions. Solar cookers are being used in many homes to cook food [11].

Solar energy can be used with the help of “photo voltaic cells” for producing electricity for driving vehicles and for illumination. Since this is an unfailing source of energy, it would be a great advantage to develop cheap and efficient photocells or photovoltaic devices to harness solar energy. Solar radiation gets converted into electricity directly in Solar Photovoltaic (SPV) panels installed on buildings or in open spaces. This electricity can either be used as it is or can be stored in the battery to be used for domestic lighting, street lighting, village electrification, water pumping, desalination of salty water, powering of remote telecommunication repeater stations and railway signals. Solar passive buildings use solar energy in building designs and cut down on energy consumption for heating and cooling. This technology is fast gaining acceptance in urban architecture.

2.3. Fuel Cells:

Fuel cells are electrochemical devices that convert the chemical energy of a fuel directly and very efficiently into electricity and heat, thus doing away with combustion. A fuel cell consists of an electrolyte and is sandwiched between two electrodes. The most suitable fuel for such cells is hydrogen or a mixture of compounds containing hydrogen [12]. Oxygen passes over one electrode and hydrogen over the other, and they react electrochemically to generate electricity, water and heat. Fuel cells are being used in space flights and can be used in electric vehicles to dramatically reduce urban air pollution. Fuel-cell powered vehicles have very high energy conversion efficiency (almost double that of currently used engines). The emissions are significantly lower (CO_2 and water vapour being the only emissions). Fuel-cell-powered electric vehicles score over the battery operated ones in terms of increased efficiency and easier and faster refueling. Fuel cell systems are excellent candidates for small-scale decentralized power generation for commercial buildings, hospitals and airports in remote locations.

2.4. Wave and Tidal Energy:

Energy can also be obtained from waves and tides. These waves and tides are another source of energy which is perpetual and can be harnessed for generating electricity, particularly where sea water can move into Energy carried by water has also been widely used in India's hilly regions, since a wheel with pedals can be made to turn when it is put in a fast flowing stream. Flour mills of small size built on this principle were used in Kashmir for a long time. In fact, large “hydroelectric” power stations work on the same principle. A natural or artificial water fall is made to turn a modern kind of pedal wheel, called a turbine, which upon rotation generates electricity. In India, the first wave energy project with a capacity of 150 MW, has been set up at Vizhinjam near Thiruvananthapuram. A major tidal wave power project costing Rs.5000 crores, is proposed to be set up in the Hantah Creek in the Gulf of Kachchh in Gujarat [13].

2.5. Co-generation:

This is the concept of producing two forms of energy from the fuel, one form being heat and the other being electrical or mechanical energy. In a conventional thermal power plant, high-pressure steam generated by burning fuels. It is used to drive a turbine, which in turn drives an alternator to produce electric power. The exhaust steam is generally condensed to water which goes back to the boiler. The efficiency of conventional power plants is only around 35% as a large amount of heat is lost in the process of condensing. In a co-generation plant, the low-pressure exhaust steam coming out of the turbine is not condensed, but used for heating purposes in factories or houses. Thus very high efficiency levels, in the range of 75-90% can be reached. The potential of power generation from co-generation in India is more than 20,000 MW even at conservative estimates [14].

2.6. Wind Energy:

Wind energy has been used for hundreds of years for sailing, grinding grain, and for irrigation. Wind energy systems convert the kinetic energy associated with the movement of air to more useful forms of power. Wind turbines transform the energy in the wind into mechanical power, which can then be used directly for grinding, lifting water or to generate electricity. Wind turbines can be used singly or in clusters called wind farms. Windmills have been used since long in many countries, but in India they have only been recently introduced [15].

2.7. Biogas:

Cattle dung for production of biogas which is a source of energy is used for cooking. Through a simple process cattle dung is used to produce a gas that contains 55-70% inflammable methane gas, and is clear and efficient fuel for use in rural areas. Water weeds like water hyacinth, water lettuce, salvinia, hydrilla, duck weeds and algae are found to be useful supplement to cattle dung. Biogas can also be used to raise steam, which in turn may be used for running engines or machines in factories or for running turbines to generate electricity. It has been found that large biogas plants can supply the needs of a number of families or even small villages. The residual dung or the digested

slurry left after generating, biogas can be used as manure for agricultural purposes. This is an economical way of obtaining energy from organic wastes. In China and India, great efforts are being made to install tens of thousands of biogas plants in rural areas. India has tremendous potential in non-conventional sources of energy. Our diverse geographical settings help in promotion of non-conventional energy sources of energy namely solar, wind and tidal. Looking at the future potential in generating solar energy, the International Solar Alliance was established in the year 2015. Major initiatives were taken by India for the establishment of this alliance. This would help us in developing clean and green energy that would address the problems emerging due to the use of conventional sources of energy like coal, petroleum and radioactive minerals. Therefore we can say these above mentioned non-conventional sources are the energy of future. But, today our major energy sources are coal, fossil fuel, natural gas, hydropower and atomic energy. These sources of energy are known as conventional sources of energy [16,17].

3. Carrying Capacity of the Earth's Energy Base

The long-term sustainable carrying capacity for the human species on the earth varies with resource availability as well as culture and level of economic development. Thus, two measures of human carrying capacity arise:

1. The biophysical carrying capacity; and
2. The social carrying capacity.

The biophysical carrying capacity is the maximum population that can be supported by the resources of the planet at a given level of technology. The social carrying capacity is the sustainable bio-physical carrying capacity within a given social organisation, including patterns of consumption and trade [18].

The social carrying capacity therefore must be less than the biophysical carrying capacity as it will account for the quality of life. Besides, it can give us an estimate of the number of humans that can be supported in a sustainable manner at a given standard of living.

In order to estimate the human population that can be sustained by the Earth, a standard of living or level of consumption must be selected or assumed. At this point, the introduction of social issues becomes important. For instance, very high global population could be supported at a very low level of food consumption, perhaps even on the brink of starvation.

The result, however, could be a socially unstable situation. A socially sustainable carrying capacity must be based on a level of consumption that meets basic human needs of food, water and space as well as provides opportunity to enjoy socio-political rights, health, education and well-being. Another important aspect of social sustainability is equitable distribution of resources. Inequitable distribution of wealth can lead to social instability and disruption.

Future Energy Needs and Conservation

Energy is an essential input for industrial development. Energy is produced from commercial sources like coal, petroleum, hydroelectric schemes as well as from non-commercial sources like cow dung, fuelwood and agricultural wastes. Per capita consumption of commercial energy is sometimes used as an index of the economic advancement that a country has attained. India's per capita consumption of commercial energy, however, is very low. It is only one eighth of the world average.

Commercial energy accounts for a little over half of the total energy used in the country, the rest coming from non-commercial sources. Share of agriculture in commercial energy consumption has risen rapidly over the past two-and-a-half decades. Industry consumed about 78 per cent of the coal and 62 per cent of the electrical energy in the country in 1985-86. The transport sector accounted for 56 per cent of the total oil consumption during the year 1989. The energy consumption of these sectors as well as the household sector are increasing rapidly. The energy strategy, therefore, has to plan not only for an increase in indigenous availability but also aim at its efficient utilisation.

5. Development of Non-Polluting Energy Systems in India

5.1. Improved Chullahas:

In developing countries like India, the energy needs of rural poor are mostly met by burning fire wood. Traditional methods of cooking are very unhealthy for the cook, as they emit a lot of smoke. Also the heat released in burning is not efficiently utilised. Indian energy scientists have come up with smokeless stoves (chulhas) specially

designed for Indian conditions. These 'Chulhas' are smokeless, permit shorter cooking time and there is also saving of fuel. In India, the overall renewable energy capacity targets have been raised from 35,776 MW in 2015 to 1,75,000 MW by 2022 (MOEF & CC, 2015). This comprises of 1,00,000 MW solar, 60,000 MW wind, 10,000 MW Biomass and 50,000 MW. The improved 'chulha' has invoked tremendous response and positive action from all concerned. Nearly 3,000 villages have been rendered 'smokeless' in the sense that in each house of these villages, either an improved 'chulha' or a biogas plant is used for cooking food. A trained work force of more than 50,000 persons, mainly women, was created to work as master craftsmen for constructing the improved chulhas [19].

5.2. Energy from City Sewage:

The city sewage treatment plants use anaerobic digestion units for extracting methane from human wastes which is in the form of sludge. The gas generated from the sludge is called sludge gas, which like biogas consists largely of methane. The Department of Non-Conventional Energy Sources has supported setting up sewage based biogas plants in Uttar Pradesh, Madhya Pradesh and Delhi.

One large size urban waste recycling plant is already operating at Okhla, Delhi. The plant comprises 15 digesters connected to 15 gas collectors. The total gas generation from the plant is about 0.6 million cubic feet per day having a heat value of 700-800 "BTU" per cubic foot (equivalent to 500-570 cal per m³). The gas is being supplied to about 800 households over an area of four kilometers. The gas is about 50 per cent cheaper than the LPG gas. Another such project has been commissioned, recently at Pandraune in UP. Plants are under construction at Ayodhya in UP, Eshaopur in Delhi, and at Bhopal in MP. In Jabalpur, Municipal Corporation is setting up a garbage-based power plant to generate 7 MW electricity daily.

Many bio-organic wastes are released as by-products by distilleries in India. A new technology for waste recycling and disposal has been introduced for the first time in the country by a distillery in Gujarat. The technology, simultaneous with the treatment of 45,000 litres of waste, will generate energy equivalent to that given by 10 tonnes of coal every day. The fuel is generated from the waste after fermenting the ash with yeast in a suitable culture medium. The 10 million litre capacity distillery can get 50 percent of its fuel requirement from recycling its own waste. If all the 150 distilleries in the country adopt the technology there could be a saving of Rs 30 crores or 5,00,000 tonnes of coal annually. This will also result in an environmentally safe disposal of wastes [17,20]

5.3. Solar Energy:

Biogas is a cheap and efficient fuel and its feedstock is renewable. More recently, other renewable sources for energy generation are being explored. Systematic efforts are being made to tap solar energy for meeting the demand so for rural poor. It is a decentralized energy system, which can be used to meet versatile needs of the Indian masses [11,21].

Solar cooking, water heating, water desalination, space heating, crop drying, etc. are some of the modes of thermal conversion. Efforts are on to economically develop solar collectors for high temperature applications. More than 380 solar water heating systems are operating in the country. More than 1,000 large capacity water heating systems are under installation.

Solar energy can also be converted into electrical energy. Solar panels concentrate large amounts of light energy on photovoltaic cells which charge the batteries that serve as a source of electricity. This electricity can be used to run pumps, street lighting system or even refrigerators. More than 160 solar photovoltaic pumps have been installed in the rural areas providing water for drinking and irrigation. Solar photovoltaic street lighting systems have been provided by Government of India in more than 150 villages on experimental basis. Installed in the remote villages, also known as Urja grams, far from power lines, solar energy makes electricity available to people who would otherwise not be able to dream of thermal or hydel electrical energy.

5.4. Wind Energy:

Another renewable alternative source of energy is wind energy. Wind energy holds promise for systematic utilization. The maximum exploitable potential has been estimated at about 3.2 x 10⁸ J/year. It can be converted into mechanical and electrical energies and would be particularly useful in remote areas. Wind energy can be made to run turbine to generate electricity. According to Indian Meteorological Department average annual wind density of 3 kWh/m²/day

(read as kilowatt hours per square meter per day) is prevalent at a number of places in Peninsular and Central India. In some areas, the densities are higher than $10\text{kwh/m}^2/\text{day}$ during winter when energy requirements are very acute and $4\text{kwh/m}^2/\text{day}$ for 5-7 months in a year. At present this energy is being used to up well ground water at four locations of Ajmer in Rajasthan [22].

DNES has installed 924 wind pumps throughout the country. Wind electricity generators at appropriate locations (like Ladakh) are envisaged with aggregate capacity of 2 MW, for lighting and pumping water in addition to devising charging of batteries. In the 8th Plan, some 85 new wind-powered mills are proposed to be installed at various locations in India, where the aerodynamics of the area provides conditions suitable for this venture [23,24].

Conclusions:-

India has always shown its willingness in leadership to fight climate change. Presently, India is world's third renewable energy producer with 40% of energy capacity installed in the year 2022 (160 GW of 400 GW) coming from Renewable Sources. Ernst & Young's (EY) 2021 Renewable Energy Country Attractiveness index (RECAI) ranked India third behind USA and China. In November 2021, India had a renewable energy capacity of 150 GW consisting of solar (48.55 GW), wind (43.03 GW), hydro power (51.34 GW) and Biomass (10.62 GE). The country's vision is to achieve Net Zero Emissions by 2070, in addition to attaining the short-term targets which include:

1. Increasing renewables capacity to 500GW by 2030,
2. Meeting 50% of energy requirements from renewables,
3. Reducing cumulative emissions by one billion tonnes by 2030, and
4. Reducing emissions intensity of India's gross domestic product (GDP) by 45% by 2030.

India's experience will be valuable to other developing nations as they translate their climate pledges into actions and undertake energy transitions towards a more sustainable energy future.

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