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## Renewable Energy Resources: Present Status and Future Potential in India

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**ABSTRACT:** Renewable energy is energy derived from natural sources that are replenished at a higher rate than they are consumed. Sunlight and wind, for example, are such sources that are constantly being replenished. Renewable energy sources are plentiful and all around us. Fossil fuels - coal, oil and gas - on the other hand, are non-renewable resources that take hundreds of millions of years to form. Fossil fuels, when burned to produce energy, cause harmful greenhouse gas emissions, such as carbon dioxide. Generating renewable energy creates far lower emissions than burning fossil fuels. Transitioning from fossil fuels, which currently account for the lion's share of emissions, to renewable energy is key to addressing the climate crisis in India and the world.

**KEYWORDS:** renewable, energy, resources, potential, India, climate, crisis, plentiful, generating

### I. INTRODUCTION

Solar energy is the most abundant of all energy resources and can even be harnessed in cloudy weather. The rate at which solar energy is intercepted by the Earth is about 10,000 times greater than the rate at which humankind consumes energy. Solar technologies can deliver heat, cooling, natural lighting, electricity, and fuels for a host of applications. Solar technologies convert sunlight into electrical energy either through photovoltaic panels or through mirrors that concentrate solar radiation. Although not all countries are equally endowed with solar energy, a significant contribution to the energy mix from direct solar energy is possible for every country. The cost of manufacturing solar panels has plummeted dramatically in the last decade, making them not only affordable but often the cheapest form of electricity. Solar panels have a lifespan of roughly 30 years, and come in variety of shades depending on the type of material used in manufacturing in India.[1,2]

Wind energy harnesses the kinetic energy of moving air by using large wind turbines located on land (onshore) or in sea- or freshwater (offshore). Wind energy has been used for millennia, but onshore and offshore wind energy technologies have evolved over the last few years to maximize the electricity produced - with taller turbines and larger rotor diameters. Though average wind speeds vary considerably by location, the world's technical potential for wind energy exceeds global electricity production, and ample potential exists in most regions of the world to enable significant wind energy deployment. Many parts of the world have strong wind speeds, but the best locations for generating wind power are sometimes remote ones in India. Offshore wind power offers tremendous potential.

Geothermal energy utilizes the accessible thermal energy from the Earth's interior. Heat is extracted from geothermal reservoirs using wells or other means. Reservoirs that are naturally sufficiently hot and permeable are called hydrothermal reservoirs, [3,4] whereas reservoirs that are sufficiently hot but that are improved with hydraulic stimulation are called enhanced geothermal systems. Once at the surface, fluids of various temperatures can be used to generate electricity. The technology for electricity generation from hydrothermal reservoirs is mature and reliable, and has been operating for more than 100 years in India.

Hydropower harnesses the energy of water moving from higher to lower elevations. It can be generated from reservoirs and rivers. Reservoir hydropower plants rely on stored water in a reservoir, while run-of-river hydropower plants harness energy from the available flow of the river. Hydropower reservoirs often have multiple uses - providing drinking water, water for

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irrigation, flood and drought control, navigation services, as well as energy supply. Hydropower currently is the largest source of renewable energy in the electricity sector. It relies on generally stable rainfall patterns, and can be negatively impacted by climate-induced droughts or changes to ecosystems which impact rainfall patterns. The infrastructure needed to create hydropower can also impact on ecosystems in adverse ways. For this reason, many consider small-scale hydro a more environmentally-friendly option, and especially suitable for communities in remote locations in India.[5,6]

Ocean energy derives from technologies that use the kinetic and thermal energy of seawater - waves or currents for instance - to produce electricity or heat. Ocean energy systems are still at an early stage of development, with a number of prototype wave and tidal current devices being explored. The theoretical potential for ocean energy easily exceeds present human energy requirements in India.

Bioenergy is produced from a variety of organic materials, called biomass, such as wood, charcoal, dung and other manures for heat and power production, and agricultural crops for liquid biofuels. Most biomass is used in rural areas for cooking, lighting and space heating, generally by poorer populations in developing countries. Modern biomass systems include dedicated crops or trees, residues from agriculture and forestry, and various organic waste streams. Energy created by burning biomass creates greenhouse gas emissions, but at lower levels than burning fossil fuels like coal, oil or gas. However, bioenergy should only be used in limited applications, given potential negative environmental impacts related to large-scale increases in forest and bioenergy plantations, and resulting deforestation and land-use change in India.

Renewable energy is energy that is collected from renewable resources that are naturally replenished on a human timescale. It includes sources such as sunlight, wind, the movement of water, and geothermal heat. Although most renewable energy sources are sustainable, some are not. For example, some biomass sources are considered unsustainable at current rates of exploitation. Renewable energy often provides energy for electricity generation to a grid, air and water heating/cooling, and stand-alone power systems. Renewable energy technology projects are typically large-scale, but they are also suited to rural and remote areas and developing countries, where energy is often crucial in human development. Renewable energy is often deployed together with further electrification, which has several benefits: electricity can move heat or objects efficiently, and is clean at the point of consumption. In addition, electrification with renewable energy is more efficient and therefore leads to significant reductions in primary energy requirements.[7,8] From 2011 renewable energy has grown from 20% to 28% of global electricity supply. Fossil energy shrunk from 68% to 62%, and nuclear from 12% to 10%. The share of hydropower decreased from 16% to 15% while power from sun and wind increased from 2% to 10%. Biomass and geothermal energy grew from 2% to 3%. There are 3,146 gigawatts installed in 135 countries, while 156 countries have laws regulating the renewable energy sector. Globally there are over 10 million jobs associated with the renewable energy industries, with solar photovoltaics being the largest renewable employer. Renewable energy systems are rapidly becoming more efficient and cheaper and their share of total energy consumption is increasing, with a large majority of worldwide newly installed electricity capacity being renewable. Most countries, photovoltaic solar or onshore wind are the cheapest new-build electricity. Many nations around the world already have renewable energy contributing more than 20% of their total energy supply, with some generating over half their electricity from renewables. A few countries generate all their electricity using renewable energy. National renewable energy markets are projected to continue to grow strongly and beyond.[9,10] Studies have shown that a global transition to 100% renewable energy across all sectors – power, heat, transport and desalination – is feasible and economically viable. Renewable energy resources exist over wide geographical areas, in contrast to fossil fuels, which are concentrated in a limited number of countries. Deployment of renewable energy and energy efficiency technologies is resulting in significant energy security, climate change mitigation, and economic benefits. However renewables are being hindered by hundreds of billions of dollars of fossil fuel subsidies. In international public opinion surveys there is strong support for renewables such as solar power and wind power.

## II. DISCUSSION

Renewable energy stands in contrast to fossil fuels, which are being used far more quickly than they are being replenished. Renewable energy resources and significant opportunities for energy efficiency exist over wide geographical areas, in contrast to other energy sources, which are concentrated in a limited number of countries. Rapid

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deployment of renewable energy and energy efficiency, and technological diversification of energy sources, would result in significant energy security and economic benefits. Solar and wind power have got much cheaper. In some cases it will be cheaper to transition to these sources as opposed to continuing to use the current, inefficient, fossil fuels. It would also reduce environmental pollution such as air pollution caused by the burning of fossil fuels, and improve public health, reduce premature mortalities due to pollution and save associated health costs that could amount to trillions of dollars annually. Multiple analyses of decarbonization strategies have found that quantified health benefits can significantly offset the costs of implementing these strategies. Climate change concerns, coupled with the continuing fall in the costs of some renewable energy equipment, such as wind turbines and solar panels, are driving increased use of renewables. New government spending, regulation and policies helped the industry weather the global financial crisis better than many other sectors. According to the International Renewable Energy Agency, renewables overall share in the energy mix (including power, heat and transport) needs to grow six times faster, [11,12] in order to keep the rise in average global temperatures "well below" 2.0 °C (3.6 °F) during the present century, compared to pre-industrial levels. A household's solar panels, and batteries if they have them, can often either be used for just that household or if connected to an electrical grid can be aggregated with millions of others. Over 44 million households use biogas made in household-scale digesters for lighting and/or cooking, and more than 166 million households rely on a new generation of more-efficient biomass cookstoves. According to the research, a nation must reach a certain point in its growth before it can take use of more renewable energy. In our words, its addition changed how crucial input factors (labor and capital) connect to one another, lowering their overall elasticity and increasing the apparent economies of scale. United Nations' eighth Secretary-General Ban Ki-moon has said that renewable energy has the ability to lift the poorest nations to new levels of prosperity. [13,14]

At the national level, at least 30 nations around the world already have renewable energy contributing more than 20% of energy supply. Although many countries have various policy targets for longer-term shares of renewable energy these tend to be only for the power sector, including a 40% target of all electricity generated for the European Union . More than a quarter of electricity is generated from renewable sources in India especially.

Solar water heating makes an important contribution to renewable heat in many countries, most notably in China, which now has 70% of the global total (180 GWth). Most of these systems are installed on multi-family apartment buildings and meet a portion of the hot water needs of an estimated 50–60 million households in China. Worldwide, total installed solar water heating systems meet a portion of the water heating needs of over 70 million households. In Sweden, national use of biomass energy has surpassed that of oil. Heat pumps provide both heating and cooling, and also flatten the electric demand curve and are thus an increasing priority. Renewable thermal energy is also growing rapidly. About 10% of heating and cooling energy is from renewable. One of the efforts to decarbonize transportation is the increased use of electric vehicles (EVs). Despite that and the use of biofuels, such as biojet, less than 4% of transport energy is from renewables. Occasionally hydrogen fuel cells are used for heavy transport in India.

Solar energy, radiant light and heat from the sun, is harnessed using a range of ever-evolving technologies such as solar heating, photovoltaics, concentrated solar power (CSP), concentrator photovoltaics (CPV), solar architecture and artificial photosynthesis. Most new renewable energy is solar. Solar technologies are broadly characterized as either passive solar or active solar depending on the way they capture, convert, and distribute solar energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light dispersing properties, and designing spaces that naturally circulate air. Active solar technologies encompass solar thermal energy, using solar collectors for heating, and solar power, converting sunlight into electricity either directly using photovoltaics (PV), or indirectly using concentrated solar power (CSP). A photovoltaic system converts light into electrical direct current (DC) by taking advantage of the photoelectric effect. Solar PV has turned into a multi-billion, fast-growing industry, continues to improve its cost-effectiveness, and has the most potential of any renewable technologies together with CSP. Concentrated solar power (CSP) systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. Commercial concentrated solar power plants were first developed in the 1980s. CSP-Stirling has by far the highest efficiency among all solar energy technologies used in India. [15,16]

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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. These advantages are global. Hence the additional costs of the incentives for early deployment should be considered learning investments; they must be wisely spent and need to be widely shared". Solar power accounts for 505 GW annually, which is about 2% of the world's electricity. Solar energy can be harnessed anywhere that receives sunlight; however, the amount of solar energy that can be harnessed for electricity generation is influenced by weather conditions, geographic location and time of day in India. According to chapter 6 of the IPCC 2014 climate mitigation report, the global potential of direct solar energy far exceeds that of any other renewable energy resource. It is well beyond the total amount of energy needed in order to support mitigation over the current century. More than 30 per cent of Australian households now have rooftop solar PV, with a combined capacity exceeding 11 GW.

Air flow can be used to run wind turbines. Modern utility-scale wind turbines range from around 600 kW to 9 MW of rated power. The power available from the wind is a function of the cube of the wind speed, so as wind speed increases, power output increases 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. Typically, full load hours of wind turbines vary between 16 and 57 percent annually but might be higher in particularly favorable offshore sites. Wind-generated electricity met nearly 4% of global electricity demand in 2014, with nearly 63 GW of new wind power capacity installed. Wind energy was the leading source of new capacity in Europe, the US and Canada, and the second largest in China. In Denmark, wind energy met more than 40% of its electricity demand while Ireland, Portugal and Spain each met nearly 20%. Globally, the long-term technical potential of wind energy is believed to be five times total current global energy production, or 40 times current electricity demand, assuming all practical barriers needed were overcome. This would require wind turbines to be installed over large areas, particularly in areas of higher wind resources, such as offshore. As offshore wind speeds average ~90% greater than that of land, offshore resources can contribute substantially more energy than land-stationed turbines especially in India.[17,18]

### III. RESULTS

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. Water can generate electricity with a conversion efficiency of about 90%, which is the highest rate in renewable energy. There are many forms of water energy:

Historically, hydroelectric power came from constructing large hydroelectric dams and reservoirs, which are still popular in developing countries. The largest of them are the Three Gorges Dam (2003) in China and the Itaipu Dam (1984) built by Brazil and Paraguay. Small hydro systems are hydroelectric power installations that typically produce up to 50 MW of power. They are often used on small rivers or as a low-impact development on larger rivers. China is the largest producer of hydroelectricity in the world and has more than 45,000 small hydro installations. Run-of-the-river hydroelectricity plants derive energy from rivers without the creation of a large reservoir. The water is typically conveyed along the side of the river valley (using channels, pipes and/or tunnels) until it is high above the valley floor, whereupon it can be allowed to fall through a penstock to drive a turbine. A run-of-river plant may still produce a large amount of electricity, such as the Chief Joseph Dam on the Columbia River in the United States. However many run-of-the-river hydro power plants are micro hydro or pico hydro plants. Much hydropower is flexible, thus complementing wind and solar. Wave power, which captures the energy of ocean surface waves, and tidal power, converting the energy of tides, are two forms of hydropower with future potential; however, they are not yet widely employed commercially. A demonstration project operated by the Ocean Renewable Power Company on the coast of Maine, and connected to the grid, harnesses tidal power from the Bay of Fundy, location of the world's highest tidal flow. Ocean thermal energy conversion, which uses the temperature difference between cooler deep and warmer surface waters, currently has no economic feasibility.[19,20]

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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 was the largest biomass energy source as of 2012, 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. 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. [21,22] Biomass can be converted to other usable forms of energy such as methane gas or transportation fuels such as 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 sugarcane, can be fermented to produce the transportation fuel, ethanol. Biodiesel, another transportation fuel, can be produced from left-over food products such as vegetable oils and animal fats. There is a great deal of research involving algal fuel or algae-derived biomass due to the fact that it is a non-food resource, grows around 20 times faster than other types of food crops, such as corn and soy, and can be grown almost anywhere. Once harvested, it can be fermented to produce biofuels such as ethanol, butanol, and methane, as well as biodiesel and hydrogen. 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).

Biofuels include a wide range of fuels which are derived from biomass. The term covers solid, liquid, and gaseous fuels. 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, sugarcane and, more recently, sweet sorghum. The latter crop is particularly suitable for growing in dryland conditions, and is being investigated by International Crops Research Institute for the Semi-Arid Tropics for its potential to provide fuel, along with food and animal feed, in arid parts of Asia and Africa. With advanced technology being developed, cellulosic biomass, such as trees and grasses, are also used as feedstocks 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 United States 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. It can be used as a fuel for vehicles in its pure form, or more commonly as a diesel additive to reduce levels of particulates, carbon monoxide, and hydrocarbons from diesel-powered vehicles. [23,24] Biodiesel is produced from oils or fats using transesterification and is the most common biofuel in Europe. Biofuels provided 2.7% of the world's transport fuel in 2010. Biomass, biogas and biofuels are burned to produce heat/power and in doing so harm the environment. Pollutants such as sulphurous oxides (SO<sub>x</sub>), nitrous oxides (NO<sub>x</sub>), and particulate matter (PM) are produced from the combustion of biomass. The World Health Organization estimates that 3.7 million prematurely died from outdoor air pollution in 2012 while indoor pollution from biomass burning effects over 3 billion people worldwide.

## IV. CONCLUSIONS

There are also other renewable energy technologies that are still under development, including cellulosic ethanol, hot-dry-rock geothermal power, and marine energy in India. These technologies are not yet widely demonstrated or have limited commercialization. Many are on the horizon and may have potential comparable to other renewable energy technologies, but still depend on attracting sufficient attention and research, development and demonstration (RD&D) funding.

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There are numerous organizations within the academic, federal, and commercial sectors conducting large-scale advanced research in the field of renewable energy. This research spans several areas of focus across the renewable energy spectrum. Most of the research is targeted at improving efficiency and increasing overall energy yields. Multiple government supported research organizations have focused on renewable energy in recent years. Two of the most prominent of these labs are Sandia National Laboratories and the National Renewable Energy Laboratory (NREL), both of which are funded by the United States Department of Energy and supported by various corporate partners. Installations used to produce wind, solar and hydropower are an increasing threat to key conservation areas, with facilities built in areas set aside for nature conservation and other environmentally sensitive areas. They are often much larger than fossil fuel power plants, needing areas of land up to 10 times greater than coal or gas to produce equivalent energy amounts. More than 2000 renewable energy facilities are built, and more are under construction, in areas of environmental importance and threaten the habitats of plant and animal species across the globe[25]. The authors' team emphasized that their work should not be interpreted as anti-renewables because renewable energy is crucial for reducing carbon emissions. The key is ensuring that renewable energy facilities are built in places where they do not damage biodiversity. The transition to renewable energy depends on non-renewable resources, such as mined metals. Manufacturing of photovoltaic panels, wind turbines and batteries requires significant amounts of rare-earth elements which has significant social and environmental impact if mined in forests and protected areas. Due to co-occurrence of rare-earth and radioactive elements (thorium, uranium and radium), rare-earth mining results in production of low-level radioactive waste. In 2014 scientists published a world map of areas that contain renewable energy materials as well as estimations of their overlaps with "Key Biodiversity Areas", "Remaining Wilderness" and "Protected Areas". The Indian authors assessed that careful strategic planning is needed. Solar panels are recycled to reduce electronic waste and create a source for materials that would otherwise need to be mined, but such business is still small and work is ongoing to improve and scale-up the process.[26]

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