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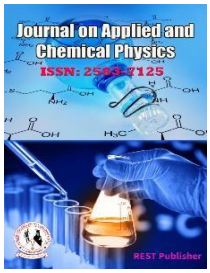

A Decision-Support System for Renewable Energy Planning in India Based on the Weighted Sum Method

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Abstract: *Energy plays a crucial role in the economic development of any nation, including developing countries like India. However, India faces a significant hurdle in its development due to a shortage of electricity. In recent years, the country's energy consumption has been rapidly increasing due to population growth and economic progress. This rapid growth has created a high demand for electricity, which is primarily met by coal power plants, thereby putting pressure on fossil fuel resources. The reliance on coal-based power generation has detrimental effects on the environment, both locally and regionally. Therefore, it is essential to enhance energy security while simultaneously reducing greenhouse gas emissions. One viable solution is the utilization of renewable energy sources, which are environmentally friendly. In the current energy landscape, it is imperative to effectively harness the potential of renewable energy. This approach not only provides a sustainable power supply but also mitigates the negative environmental impacts associated with fossil fuels. The need to harness energy from renewable sources has become more apparent due to the increasing demand for energy and the adverse effects of fossil fuels on the environment. The world is currently facing a critical phase where traditional and finite energy sources are being depleted rapidly, leading to a greater focus on renewable and sustainable energy sources. These renewable energy resources, such as solar, wind, biomass, and small hydro, are abundant and non-depletable. They have the potential to effectively meet the growing energy demand while being environmentally friendly. The progress made in wind power, solar energy, small hydro, biomass power, and co-generation in recent years has shown significant potential in generating electricity for the grid. The weights undergo systematic changes, resulting in a different optimal outcome. Initial estimates are derived from the obtained solutions. Weights assigned a value of 0 serve as non-specific reference points, and the most valuable responses can be generated in the presence of any weak similarity. It is important to note that the weighting method is specifically designed for optimization in the early stages of the sum system's development. we have taken the alternative : solar , wind, hydro biomass, geothermal.we have taken the evaluation preference : Investment cost, O&M cost, electric cost, efficiency, capacity factor, technical maturity, GHG emission, land use, job creation, social acceptance from the result it is seen that Renewable Energy Source and is The value of the dataset for Software Renewable Energy Source in Weighted sum method (WSM) method shows that it results in hydro got first rank and geothermal is last rank.*

Keywords: *Renewable energy, solar energy, biomass, solar, wind, hydro, geothermal.*

1. INTRODUCTION

Projections indicate that India's electricity consumption will reach around 2,280 billion kilowatt-hours (BkWh) by 2021-22 and approximately 4,500 BkWh by 2031-32. This surge in energy consumption is driven by population growth and improved living standards. Presently, India heavily relies on thermal power plants, which make up about 70% of its total installed capacity. However, this heavy dependence on fossil fuels raises concerns regarding sustainability and future fossil fuel reserves. Thermal power plants also contribute to environmental issues, such as significant carbon dioxide (CO2) Considering the potential for generating biogas from additional sources like animal wastes and industrial wastewater, India's overall biogas potential could significantly increase. The sun, as a fusion reactor that has been active for billions of years, provides an immense amount of solar energy to the Earth. Mills (2000) states that just one minute of solar energy is enough to meet the world's energy demands for an entire year. In fact, the sun supplies more energy in a single day than our current global population would consume in 27 years. Moreover, the solar radiation received by the Earth over a span of three days holds an energy equivalent to that stored in all existing fossil fuel sources. India stands out as a country with abundant sunshine, experiencing an annual average insolation ranging from 4 to 7 kWh per square meter per day, along with approximately 250-300 clear and sunny days each year. India has already made significant progress in harnessing new and renewable energy sources. Various solar technologies

have reached the stage of commercial utilization and have proven their technical and socio-economic viability. These include solar thermal devices and solar photovoltaic cells used for lighting, water pumping, communication, and even the generation of a significant amount of electricity from solar energy. Prior to the industrial revolution, biomass was the primary energy source for humans, encompassing all plant life on land and in water as well as organic waste. Various crops such as sugarcane, corn, sugar beets, and grains can be cultivated specifically for energy production. The suitability of a crop for energy use is determined by two factors: high yield of dry material per unit of land (dry ton/ha) and its energy-generating capabilities. Large hydro and small hydropower plants typically utilize a run-of-the-river configuration, meaning they don't require extensive reservoirs. This sets them apart from larger dams and helps minimize environmental impacts such as deforestation, submergence, and the need for rehabilitation. This configuration also reduces the project gestation period and offers greater operational flexibility. Currently, offshore wind power is experiencing rapid growth, especially in Europe, where the European Union already has around 5 GW of operational installed capacity. The advancement of next-generation turbines, which have capacities exceeding 3 MW, combined with improvements in scheduling, forecasting technology, and software, could make a significant contribution to India's renewable energy sector. Offshore wind power has the potential to become a viable source of electricity generation [11]. Wind energy refers to the energy obtained from the movement of air. Wind turbines are utilized to capture this energy by converting the kinetic energy of air motion into electrical energy through a generator. The amount of power produced by wind turbines depends on various factors such as wind speed, air density, and the area of airflow. Large-scale hydropower is a well-established technology that has proven to be effective. Small hydro plants (SHP) typically have power capacities below 25 MW. In India, SHP is classified into three categories: micro (>100 KW), mini (100 KW–1 MW), and small (1–25 MW) power plants. According to Wilson (2015), hydroelectric energy is a highly feasible and environmentally friendly option for renewable energy, especially in regions with subtropical climates. It is considered one of the most reliable and technically feasible sources of renewable energy. While hydropower requires significant initial investment, it has low operational and maintenance costs and does not incur fuel expenses [12]. Concentrated Photovoltaics (CPV) is an innovative approach for harnessing solar energy to produce electricity. It involves the use of solar concentrators, such as mirrors or lenses, to concentrate sunlight onto specialized photovoltaic surfaces designed for generating power (see Figure 1). These concentrators are often installed on solar trackers to ensure that the focal point remains on the photovoltaic module as the sun moves across the sky. CPV plants utilize this concentrated solar radiation to directly convert it into electricity using photovoltaic modules [11]. In comparison to traditional flat-plate photovoltaic systems, the solar cells employed in CPV systems are typically more costly. CPV technology has advanced in various forms, including single-axis tracking with line focus CPV and two-axis tracking with point focus CPV. However, recent developments have mainly focused on two-axis tracking systems for point focus CPV [13]. Biomass refers to the organic matter derived from plants and animals, including their waste from various sources such as domestic and industrial activities, agricultural residue, and agro waste. Through processes like combustion or natural metabolic reactions, biomass reacts with oxygen and produces heat at temperatures exceeding 400°C. These organic waste materials are utilized as fuel to generate electricity. The energy potential of biomass has always been significant for the country. Geothermal energy, on the other hand, The potential applications of geothermal energy are vast and depend on the availability of this resource. Tidal energy technologies harness the power generated by the movement of ocean tides. Tidal energy generation involves the construction of barriers or barrages that create a reservoir. The tidal water then passes through turbines, which convert its kinetic energy into electricity**.**

2. MATERIALS & METHODS

Solar: It is an environmentally friendly and sustainable energy source since sunlight is abundant and freely available. Various technologies, such as solar panels (photovoltaic cells) and solar thermal systems, are utilized to harness solar energy. Solar panels directly convert sunlight into electricity, while solar thermal systems use sunlight to generate steam or heat water. Solar energy offers numerous environmental advantages as it does not produce greenhouse gas emissions and decreases reliance on fossil fuels. Furthermore, solar power has become more affordable and prevalent, making it a viable alternative to traditional energy sources in many regions worldwide.

wind: Wind is the term used to describe the inherent motion of air within the Earth's atmosphere. It arises due to variations in air pressure, resulting in the formation of air currents that move from regions of high pressure to areas of low pressure. The presence of wind is vital in shaping weather patterns and facilitating the dispersion of heat and moisture across the planet. Its intensity can range from gentle zephyrs to forceful gusts, and its course and strength are influenced by factors such as geographical features, temperature differentials, and the Earth's rotation. Additionally, wind power, obtained by harnessing wind energy using turbines, serves as a renewable and increasingly utilized source of electricity generation.

Hydro: Hydro, often used as a shortened term, typically refers to hydroelectric power or hydroelectricity. Hydroelectric power is a renewable energy source that involves harnessing the energy from flowing water, like rivers or waterfalls, to generate electricity. Hydroelectric power is recognized for its cleanliness and sustainability, as it

doesn't release greenhouse gases during operation and relies on the natural water cycle. It is widely adopted globally as a dependable and effective means of generating electricity.

Biomass: Examples of biomass include wood, agricultural residues, dedicated energy crops, and organic waste. Through processes like combustion, gasification, or anaerobic digestion, biomass can be transformed into different forms of energy, such as heat, electricity, and biofuels. The utilization of biomass as an energy source offers several advantages. Firstly, biomass is abundant and widely available. Secondly, it is considered carbon-neutral since it only releases the carbon it previously absorbed during its growth, making it a more environmentally friendly alternative to fossil fuels. Furthermore, biomass utilization can contribute to waste management by repurposing organic materials that would otherwise be discarded.

Geothermal: Geothermal energy is the heat energy stored and generated within the Earth, serving as a renewable energy source with multiple applications. Power plants that harness geothermal energy utilize the Earth's internal heat, often by accessing underground hot water or steam reservoirs, which then drive turbines connected to generators to produce electricity. Additionally, geothermal energy can be employed for heating and cooling purposes in various settings, such as residential, commercial, and industrial, by utilizing geothermal heat pumps. By tapping into the Earth's natural heat, geothermal energy presents a sustainable and eco-friendly alternative to conventional fossil fuel-based energy sources.

O&M cost: Investment cost encompasses the monetary outlay necessary for obtaining an asset, initiating an investment, or commencing a business endeavour. This encompasses a range of expenditures, including the acquisition of equipment, property, or stocks, as well as costs related to research and development, marketing, staffing, and operational functions. The consideration of investment cost is crucial for both individuals and businesses, as it directly influences the financial viability and potential gains associated with an investment.

Electric Cost: Electric cost refers to the monetary expenditure associated with the consumption of electricity. It encompasses the financial obligations borne by individuals, households, or businesses in relation to the electrical energy they utilize. Various factors contribute to determining electric costs, including the utility company's rate structure, the quantity of electricity consumed (measured in kilowatt-hours), and any supplementary charges or fees. The actual expenses can fluctuate based on factors like geographical location, seasonal variations, usage patterns, and the efficiency of electrical devices and systems.

Efficiency: Efficiency is the capacity to complete a task or reach a goal while minimizing unnecessary effort, time, or resources. It encompasses the optimization of processes, the maximization of output, and the minimization of input. In different scenarios, efficiency can be evaluated based on various factors such as productivity, cost-effectiveness, speed, accuracy, or resource utilization. The enhancement of efficiency typically involves streamlining workflows, eliminating superfluous steps or redundancies, implementing automation or technological solutions, improving communication and collaboration, and continually seeking opportunities to optimize performance. By prioritizing efficiency, both individuals and organizations can increase productivity, reduce costs, and achieve better outcomes.

capacity factor: The term "capacity factor" pertains to the proportion of a power plant or energy-generating system's actual output compared to its maximum potential output at full capacity within a specific timeframe, typically presented as a percentage. This metric holds significant importance in the energy sector as it assists in evaluating the efficiency and dependability of a power plant. A higher capacity factor signifies that the plant is operating near its maximum capacity, indicating greater efficiency. Conversely, a lower capacity factor indicates that the plant is not fully utilizing its potential output.

Technical maturity: Technical maturity refers to the degree of advancement, stability, and preparedness of a technology or system. It evaluates how extensively a technology has been tested, improved, and proven to be effective and dependable for its intended purposes. A technically mature technology or system has undergone thorough research, development, and testing, demonstrating its functionality, performance, and safety. It has reached a stage where it is considered reliable, resilient, and suitable for real-world applications. Factors that contribute to technical maturity include innovation levels, the presence of supporting infrastructure, adherence to industry standards, component or subsystem reliability, and successful implementation and validation in relevant environments. Evaluating technical maturity is crucial for informed decision-making regarding technology adoption or investment. It helps ascertain whether a technology is ready for widespread use, whether it requires further development or refine

Land use: Land use pertains to the utilization and allocation of land for various purposes, encompassing residential, commercial, industrial, agricultural, recreational, and conservation aims. It encompasses the strategic organization, administration, and enhancement of land to fulfill diverse societal needs and objectives. Decisions regarding land use play a vital role in establishing the spatial arrangement and purpose of various activities within a specific region. These decisions necessitate the assessment of economic, environmental, social, and cultural factors, alongside adherence to zoning regulations and urban planning principles. The achievement of sustainable development and optimal utilization of limited land resources heavily relies on effective land use planning and management.

Job creation: Job creation encompasses the act of generating fresh employment prospects within an economy. Its objective is to establish novel job positions or enhance existing ones across different sectors and industries. Job creation plays a pivotal role in fostering economic growth by reducing unemployment rates, boosting incomes, and enhancing

living standards. There are multiple avenues through which job creation can be realized. One key source is the growth and expansion of businesses. As businesses experience progress, they frequently necessitate additional personnel to meet the heightened demand for their products or services. This can entail hiring new staff, extending work hours for existing employees, or broadening operations to new geographical areas.

Social acceptance: Social acceptance refers to the recognition and approval of an individual or a group by others within a particular society or community. It involves being embraced, respected, and included by others, regardless of differences in beliefs, values, or characteristics. Social acceptance plays a significant role in shaping individuals' self-esteem, sense of belonging, and overall well-being. It is often influenced by cultural norms, societal expectations, and personal biases, and it can vary across different social contexts and groups. Achieving social acceptance typically involves conforming to certain standards or behaviors that are considered desirable or appropriate within a given social setting.

3. WEIGHTED SUM METHOD (WSM)

The proposed approach in the multi-criteria decision for weighted sum method (WSM) involves ranking cameras. The system calculates the preference score of alternative cameras using the WSM approach. The WSM method assigns relative weights to team scores and features, while customer reviews are used as scores Solar thermal power plants, also known as STE plants, function similarly to conventional power stations by generating electricity. These plants are particularly beneficial in addressing climate change and reducing reliance on fossil fuels in a cost-effective manner. Projections suggest that by 2020, India could have an installed capacity of 4-5 GW for STE. Notably, regions like Delhi, Haryana, Punjab, and Gujarat heavily rely on Indian STE output, which is supplied from sites in Rajasthan and Jammu and Kashmir. Consequently, there is a growing emphasis on alternative energy sources like wind, solar, and hydrogen. Wind power has emerged as a highly effective option due to its advanced technology, existing infrastructure, and cost attractiveness. It is a renewable energy source that doesn't emit carbon dioxide (CO2), thus aiding in the mitigation of global warming. Wind turbine generators (WTGs) have been utilized for over a century to generate electricity. Employing WTGs for renewable energy is regarded as one of the most feasible methods of power generation, providing favorable economic and environmentally friendly impacts. In India, biogas plants play a crucial role in producing approximately 2.2 million cubic meters of natural gas. These plants are used to supply gas for various purposes such as cooking, lighting, and power generation. Specially designed burners are utilized for cooking with biogas, and biogas plants with a capacity of 2 cubic meters are suitable for households with four to five members. Biomass serves as the fuel for gas lamps, with approximately 0.13 cubic meters of biogas needed per hour for a 60-watt lamp. [24]. The power generation industry heavily relies on natural resources such as water and fossil fuels. In India, a significant portion of electricity generation is based on thermal power plants fueled by coal. India possesses approximately 6% of the world's coal reserves and has considerable hydroelectric potential estimated at around 84,000 MW with a 60% plant load factor. However, the distribution of hydroelectric potential in the country is uneven, primarily concentrated in the northern and northeastern regions. Fossil fuels, including coal, oil, and gas, are finite resources and their extraction and utilization have adverse environmental impacts, such as mining-related activities, deforestation, emissions of particulate matter, waste management, and reliance on transportation, among others. Large-scale hydroelectric projects also pose significant environmental, social, and economic challenges [25].

4. RESULT AND DISCUSSION

TABLE 1 Renewable Energy Source

	efficiency	**capacity factor**	**technical maturity**	**job creation**	**social acceptance**	**Investment cost**	**O&M cost**	**electric cost**	**GHG emission**	**land use**
solar	20	15	5	0.87	4.76	4550	30	6.74	85	150
wind	35	27	4	0.17	4.51	3005	60.86	2.4	26	200
hydro	90	25	5	0.27	4.19	2040	14.85	1.7	26	500
biomass	25.3	54	3	0.21	3.78	3370	99.4	3.25	45	222
geothermal	11.4	71.7	2	0.25	4.11	3920	112.6	4.93	50	100

Table 1 shows the Alternative: solar, wind, hydro biomass, geothermal. Evaluation preference: investment cost O&M cost, electric cost, efficiency, capacity factor, technical maturity, GHG emission, land use, job creation, and social acceptance

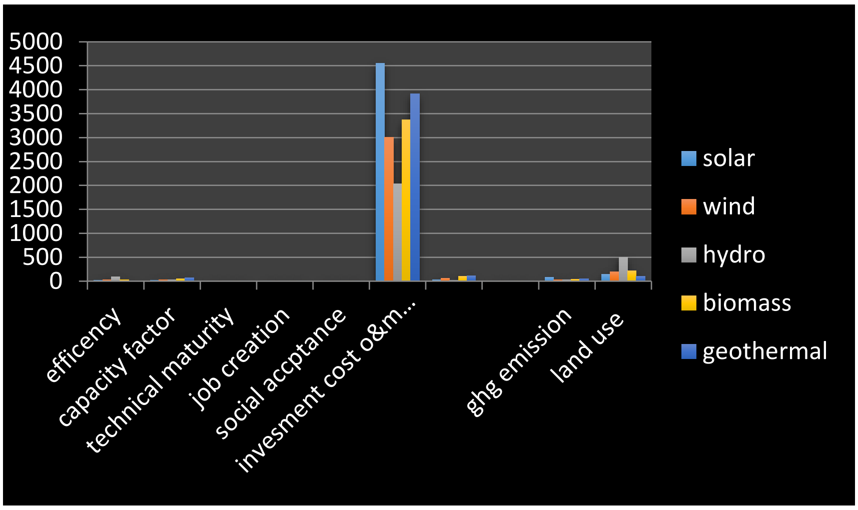

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TABLE 2. Normalized Data

Normalized Data									
0.22222	0.20921	1.00000	1.00000	1.00000	0.44835	0.49500	0.25223	0.30588	0.66667
0.38889	0.37657	0.80000	0.19540	0.94748	0.67887	0.24400	0.70833	1.00000	0.50000
1.00000	0.34868	1.00000	0.31034	0.88025	1.00000	1.00000	1.00000	1.00000	0.20000
0.28111	0.75314	0.60000	0.24138	0.79412	0.60534	0.14940	0.52308	0.57778	0.45045
0.12667	1.00000	0.40000	0.28736	0.86345	0.52041	0.13188	0.34483	0.52000	1.00000

Table 2 shows the Normalized data for Alternative: solar, wind, hydro biomass, geothermal Evaluation preference: investment cost O&M cost, electric cost, efficiency, capacity factor, technical maturity, GHG emission, land use, job creation, and social acceptance

TABLE 3. Weights

Weights									
0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10

Table 3 shows Weight ages used for the analysis. We take same weights for all the parameters for the analysis.

TABLE 4. Weighted normalized decision matrix

Weighted normalized decision matrix									
0.86036	0.85518	1.00000	1.00000	1.00000	0.92292	0.93210	0.87132	0.88829	0.96026
0.90988	0.90695	0.97793	0.84936	0.99462	0.96201	0.86844	0.96610	1.00000	0.93303
1.00000	0.90000	1.00000	0.88958	0.98733	1.00000	1.00000	1.00000	1.00000	0.85134
0.88082	0.97205	0.95020	0.86750	0.97721	0.95104	0.82686	0.93725	0.94662	0.92335
0.81333	1.00000	0.91244	0.88276	0.98542	0.93677	0.81662	0.89900	0.93670	1.00000

Table 4 shows the weighted normalized decision matrix for Alternative: solar, wind, hydro biomass, geothermal Evaluation preference: investment cost O&M cost, electric cost, efficiency, capacity factor, technical maturity, GHG emission, land use, job creation, social acceptance is also Multiple value.

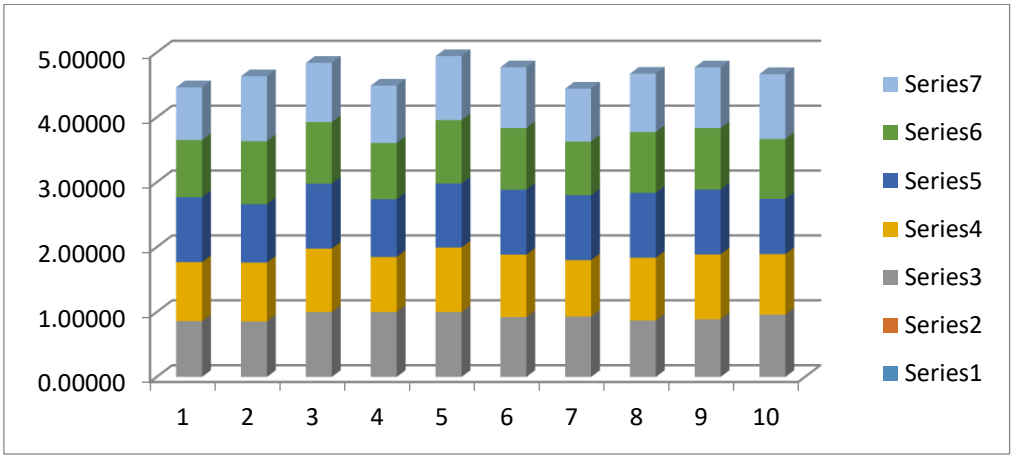

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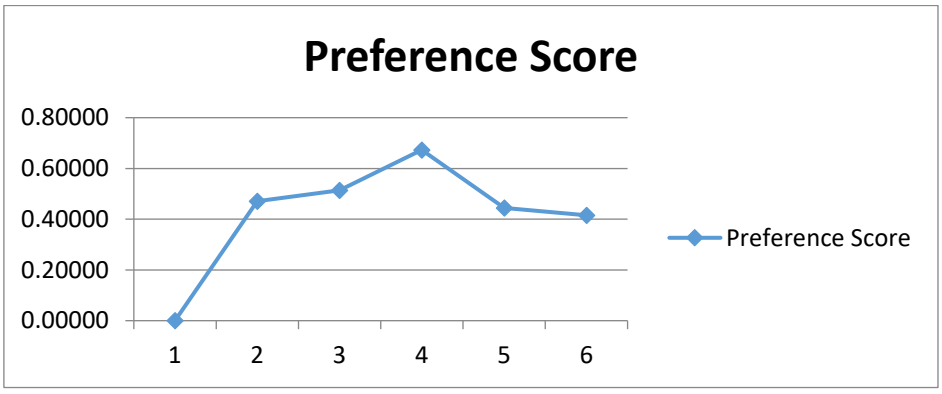
TABLE 5 Preference Score & Rank

Preference Score	Rank
0.47042	3
0.51341	2
0.67296	1
0.44430	4
0.41586	5

Table 5 shows the final rank of this paper solar is in 3rd rank, wind is in 2nd rank, hydro is in 1st rank, biomass is in 4 th rank, geothermal is in 5th rank. The final result is done by using the WSM method.



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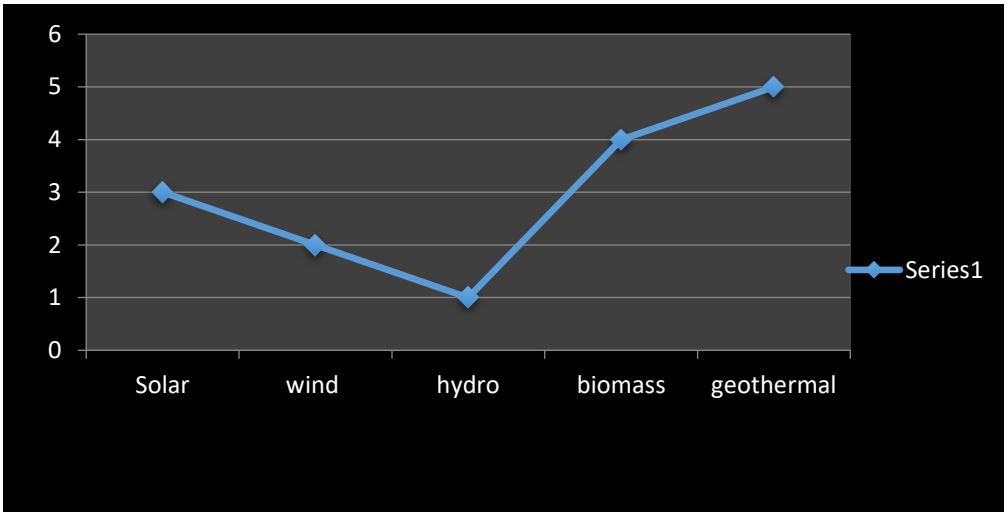

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5. CONCLUSION

The assessment of unconventional energy sources in India has demonstrated their significant potential in meeting the country's current energy demand. Wind energy has achieved 56.37% of its potential, SHP projects account for 7.60%, biomass power represents 14.51%, solar power contributes 21.46%, and other resources make up 0.30%. As India experiences rapid economic growth, its energy consumption is expected to increase substantially. However, relying heavily on coal and imported oil for energy supply poses challenges in terms of maintaining low greenhouse gas The significance of renewable energy in India is projected to increase in the future due to its potential to reduce greenhouse gas (GHG) emissions and decrease crude oil imports. Although India has initiated renewable energy programs early on, it lags behind certain countries and regions in some renewable energy technologies. This underestimation of renewable energy's role in future energy supplies can be attributed to the lack of reliable estimates for the potential of most renewable sources, as well as a significant underestimation of sources like biomass. India boasts the world's largest small gasifier program and the second-largest biogas and Improved Cook Stoves programs. However, a considerable number of installed biogas plants are no longer operational, and it is estimated that less than 6 million out of the 35 million installed ICSs are currently in use

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