



GEOGRAPHIC INSIGHTS INTO ENERGY TRANSITION: RENEWABLE ENERGY POTENTIAL IN HARYANA

Dr. Puja Bishnoi

Associate Professor of Geography, Government College, Raipur Rani (Panchkula)

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ABSTRACT

This study examines the unique situation of Haryana, an Indian state in the north known for its large industrial and agricultural activity, as the globe struggles to shift to sustainable energy sources. In order to shed light on its potential to aid in the broader energy transition, the study investigates the unrealized renewable energy potential inside the bounds of Haryana. This study offers insights into the practicality and feasibility of renewable energy sources, notably solar and wind power, in Haryana through a thorough investigation of geographical and environmental aspects, such as sun irradiation, wind patterns, and land availability. Additionally, it takes into account the socioeconomic and political factors that affect the adoption of renewable energy technology in this area. This study examines these geographic insights in an effort to educate energy policymakers, investors, and stakeholders about the opportunities and difficulties of advancing Haryana's renewable energy agenda, ultimately advancing global efforts for a more environmentally friendly and sustainable energy future.

KEYWORDS: *Renewable Energy Potential, Geographic Analysis, Energy Transition, Haryana, Solar and Wind Power*

1. INTRODUCTION

Starting around 2020, India's yearly emanations of ozone depleting substances rank third worldwide, with the energy business being a key supporter. Policymakers will profit from taking a gander at the potential for clean energy and the limit of the different states to set the energy transition before long. An intensive assessment of the perplexing elements influencing the Indian energy area is expected to put India on the way of the energy transition. This section puts major areas of strength for an on a speedy assessment of the issue definition, recommended work, goal, need, and extent of the proposal, as well as the postulation's association. It is obvious from the



writing survey that various examinations are being proposed for planning procedures, approaches, recreating situations, and exploring explicit situation analysis, strategy, financial, and techno-monetary subjects of individual system towards energy transition to really decarbonize the energy area or to advance clean energy infiltration. There are, in any case, very few examinations that analyse the nations or alternately area's ability for energy transition and give importance to specific geographic locales.

Additionally, the studies do not examine the capacity for the states or nations to go through an energy transition in light of the numerous variables that can affect the shift to clean energy. There are, however, very few studies that push the nation in the direction of an energy transition, and none that highlight the significance of certain obstacles and tactics that are specific to the Indian environment.

This is accomplished by applying MCDA approaches that are straightforward and reliable but are based on distinct frameworks, such as TOPSIS and Multi-Objective Optimisation Method by Ratio Analysis (MOORA). In order to compare the outcomes of each strategy, a comparative analysis is done. On the other hand, giving more weight to the factors that support such a change is essential if we are to steer the current power sector scenario towards a clean energy transition.

To precisely plan the pertinence of SWOT parts as per the requirements that should be modified in the current situation to make it into a superior forthcoming situation, fluffy AHP is used. Since PROMETHEE strategy depends on an outclassing structure, it has the ability to create a top to bottom assessment of different techniques when contrasted with other MCDA systems. When contrasted with different philosophies, the PROMETHEE approach can be utilized to look at a great many components and choices with dependable outcomes.

To evaluate India's potential for a sustainable energy transition while concentrating on its seven largest power-producing states. This is accomplished by applying MCDA approaches that are straightforward and reliable but are based on distinct frameworks, such as TOPSIS and Multi-Objective Optimisation Method by Ratio Analysis (MOORA).

The effectiveness of the suggested strategies is determined by their capacity to coordinate the favourable SWOT elements and revitalise the adverse SWOT components. Therefore, the path that this study indicates using the SWOT-MCDA framework can be very helpful to policymakers. India has set itself elevated focuses to expand the reception of renewable energy, and starting around 2017, significant progressions have been made. Notwithstanding, petroleum products represent a critical piece of the energy blend in India. An intensive assessment of the perplexing elements influencing the Indian energy area is expected to put India on the way of the energy transition. This study is proposed to assess the opportunities for the change to clean energy through an engaged survey of India's seven biggest power-creating states. This report is being introduced to frame the momentum energy transition situation in India and to point the energy area toward a potential situation for accomplishing a consistent energy transition. Figure 1 purposes different MCDA strategies to show the potential for clean energy.

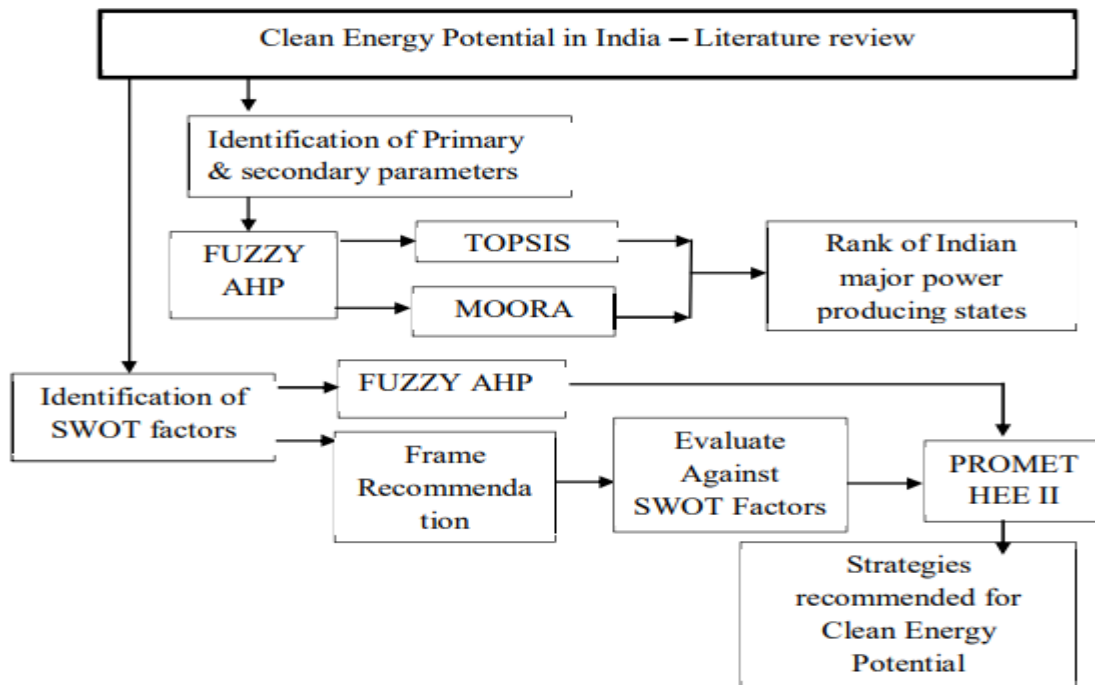


Figure 1: Assessment of clean energy potential using different MCDA methods



2. LITERATURE REVIEW

Reddy (2016) created a green economy scenario by working from the ground up. By 2030, significant resource savings could be achieved through the adoption of green technology and increased energy efficiency. By promoting the green economy, 10 million more jobs will be available, and paths out of poverty will be opened up. Moallemi et al. (2017) utilized strategy analysis and a story informed exploratory displaying way to deal with assesses the energy transition ways of the Indian electrical framework. This methodology exhibited how far-fetched it is for the 100 GW solar power objectives to be reached and how the public authority's dynamic cooperation in the energy transition would be significant to future advancement. With energy capacity advancements including batteries, siphoned hydro capacity, nuclear power stockpiling, packed air energy capacity, and power-to-gas innovation, Gulagi et al. (2017) analysed a 100 percent renewable energy entrance situation in India. The findings of Gulagis et al. (2018) recommend that a levelized cost of energy (LCOE) of vast situation will empower 100 percent renewable energy reception in 2050. Moreover, energy capacity advancements have an essential impact in giving the energy framework adaptability, and battery energy capacity advances right now supply 42% of the world's complete power utilization. In India, the solar-PV and battery energy capacity frameworks stand out as the most economical choice. A revised strategy was put forth by Yadav et al. (2018) to enable solar home systems for achieving rural energy transformation, particularly in low-income areas. This is achieved by including an electronic mechanism for disbursing subsidies, which can build the productivity and adequacy of capital endowment programs for solar-powered homes.

In India, Harrington et al. (2020) examined the variations in basic illumination during the rural household energy transition. The findings highlighted the fact that micro grid connected homes have fewer appliances than grid connected ones. According to Kumar et al. (2020), in order to achieve energy sustainability, the energy sector's dependence on fossil fuel resources should be upgraded to depend on clean energy resources. Azad and Chakraborty (2020) suggested an Energy Policy with Equity for India. This strategy uses taxed money to fund renewable energy projects and, up to a point, free electricity for households.



A research by Jain et al. (2020) examined the potential of India's solar and wind energy resources. In 2020, Madurai Elavarasan et al. studied the policies, problems, and advancement of renewable energy in Indian states. Irfan and others (2021) A key step in developing efficient and sustainable energy policies is determining the public's willingness to use different energy technologies. Energy policies must be in line with the interests and attitudes of the general population because energy production and consumption have significant effects on the environment, economy, and society. Policymakers may develop plans that are not only technically feasible but also socially and politically viable by understanding how the public feels about various energy technologies. Studying public acceptance is important because it can affect whether renewable and clean energy technologies are adopted and put into use. Climate change mitigation and greenhouse gas emission reduction depend heavily on renewable energy sources like solar, wind, and hydroelectricity. But the acceptance and use of these technologies by the general population is frequently essential to their success. The transition to greener energy sources may be hindered if the public is unwilling to embrace or use renewable energy sources because to worries about aesthetics, dependability, or affordability. To successfully address these issues and advance the switch to sustainable energy sources, policymakers must evaluate these concerns.

The paradox of India's energy transition which is linked to a growing use of coal while making rhetorical success in renewables was illustrated by Roy & Schaffartzik in 2021. The results show that a variety of intricate, multifaceted factors influence coal choice, allowing coal to predominate and impeding the energy transition. Fragkos and others (2021) Understanding the global transition to a more sustainable and eco-friendly future requires investigating national low-carbon scenarios in a diverse group of nations, including Australia, Brazil, Canada, China, the EU-28, India, Indonesia, Japan, the Republic of Korea, Russia, and the USA. The population, economy, and carbon emissions of these nations account for a sizeable share of global emissions. The strategy each country takes to meet its low-carbon objectives is a reflection of its particular socioeconomic and environmental conditions, as well as its political and technological capabilities.



Australia, for instance, has been struggling to reduce emissions from its fossil fuel-dependent economy due to its abundant natural resources and an energy industry that is focused on exports. Brazil, on the other hand, must simultaneously address emissions from its increasing agriculture and energy industries while also reducing deforestation in the Amazon rainforest. In order to achieve its goal of lowering greenhouse gas emissions, Canada must strike a balance between the interests of its resource-rich provinces and its attempts to transition to a low-carbon economy. China, the top carbon dioxide emitter in the world, is crucial to the transition to a low-carbon world. Its aggressive renewable energy goals, adoption of electric vehicles, and emission reduction plans have significant effects on both domestic and global efforts to battle climate change. The EU-28, a confederation of 28 European nations, has been in the forefront of the fight against climate change with its policies aimed at lowering emissions, boosting the use of renewable energy sources, and establishing a circular economy.

With a fast increasing population and energy consumption, India must balance its growth aspirations with environmental sustainability. As an expanding nation, Indonesia must balance the need for economic expansion with reducing emissions from the energy industry and deforestation. With cutting-edge technology, Japan and the Republic of Korea are working to switch to cleaner energy sources while keeping their industrial competitiveness. It is a difficult and intricate task to perform a dynamic analysis for terawatt-scale renewable energy systems in India in order to calculate the necessary energy storage. Jain et al. As it aids in comprehending the erratic and variable nature of renewable sources like wind and solar, such a study is essential for the successful integration of a significant amount of renewable energy into the grid. This kind of study is essential for efficient energy planning in India, where the demand for energy is continually rising and environmental concerns are driving a switch to cleaner energy sources.

A thorough dynamic study would first need gathering a sizable amount of information on renewable energy sources, such as solar irradiance and wind speeds, throughout various Indian locations. Understanding the seasonal and nocturnal fluctuations in energy production from these sources depends on this data. To evaluate how renewable energy may be integrated into the current infrastructure, it would also be important to have historical data on energy consumption



trends and grid behaviour. Godil et al. (2021) examined the variables affecting India's energy consumption using the Quantile Autoregressive Distributed Lag (QARDL) approach. The energy solutions proposed by Saraswat and Digalwar (2021) were evaluated based on technical, economic, environmental, social, political, and flexible factors. The findings showed that solar energy, followed by wind and hydropower is the best energy solution for promoting energy sustainability in India. The same group of researchers used an empirical inquiry and the validation of indicators in another study to examine India's energy sources using the sustainability importance index.

In order to understand the role of the interaction of knowledge politics, vulnerability, and recognition-based energy justice, Pandey & Sharma (2021) presented three examples of renewable energy transition projects. Public participation is essential for achieving energy transition, according to the study.

3. RESEARCH METHODOLOGY

Finding and utilising any location's potential for wind energy requires accurate estimation and mapping of wind speed. In this chapter, the wind energy potential in the southern regions of India—Haryana and Haryana State, which are located between 12°41' and 22°N latitude and 77° and 84°40'E longitude—is estimated and mapped. Measured parameters are used to forecast wind speed, and a parametric analysis is also done for precise prediction. For each location, measurements of meteorological variables like pressure, temperature, relative humidity, and wind speed are made. MATLAB was used to consider generalised feed-forward with back-propagation neural networks. Data analysis for a certain set of input parameters opens this chapter. The general modelling process is then described, along with a brief discussion of the ANN approach, model training, and model testing. Following a description of how to optimise an ANN model for precise prediction, the mapping of wind energy potential using a GIS approach is discussed. The ideal type of land that is available for wind farms in Haryana and Haryana State is estimated using data on land use and land cover.



India Meteorological Department (IMD), a government organisation, records and archives the meteorological characteristics in India. Several weather monitoring sites in other states, including IMD, have equipment installed to measure wind speed. In Haryana and Haryana State (a total area of 2, 72,282 km²), there are 28 base stations being monitored by IMD, Pune, which have collected data on wind speed. Accurate wind speed statistics for Haryana and Haryana State are not available at the local level outside of these sites. The lack of reliable data on wind speed makes it difficult for academics and decision-makers to pinpoint the best locations for wind farms and gauge local wind potential. By pinpointing the important variable that has a significant impact on wind speed prediction, the current work seeks to overcome these constraints. Furthermore, a model is created utilising the available meteorological data to forecast the wind speed at any given place, even in the absence of measured data.

Four meteorological factors, including temperature (T), station-level pressure (P), relative humidity (RH), and wind speed (WS), have been taken into account in this study. These four metrics are all considered as monthly means. For a span of 20 years (1995-2015), data have been collected and archived by IMD, Pune at 28 locations in Haryana and Haryana State. These data sets, which are listed in Appendices I, II, and III, were obtained from IMD, Pune for research purposes. It was discovered that the data that had been recorded had some gaps. Such data was rejected because the parameters were either not measured or measured with an error of more than 5%. At ground stations, measuring equipment was used to take measurements of all the meteorological parameters. A height of 10 metres was used to gauge the wind speed. Over a 20-year period, each metric had monthly mean values for all 12 months. Four parameters' data were acquired for 28 locations, resulting in 6,720 data points for each parameter and 26,880 total data points. Following the calculation of monthly mean values for each parameter using this data, an ANN model was developed and evaluated. Three sets of data, each containing information for 20, 4, and 4 sites, were created from the data collected by 28 weather monitoring stations. The ANN model was trained using a first data set of 20 locations, followed by a second data set of 4 sites for model validation, and a third data set of 4 locations that was set aside to test the model's accuracy. Testing site and training location were divided when creating the model in order to assess the model's propensity for prediction at novel places. Within HARYANA and

HARYANA State, a random location is chosen for the test. Each input data set includes the typical month of the year at each station, as well as means meteorological and topographical parameters. As a result, each station has 12 data sets, which include input and output data. In order to assess the model's predictive power, 288 data sets are used to train and validate it, and 48 data sets are utilised to test it. Figure 2 depicts the physical location of HARYANA and HARYANA State as well as the locations of the weather monitoring stations from which the measured data was collected. Table 1 provides the geographic characteristics of these ground stations.

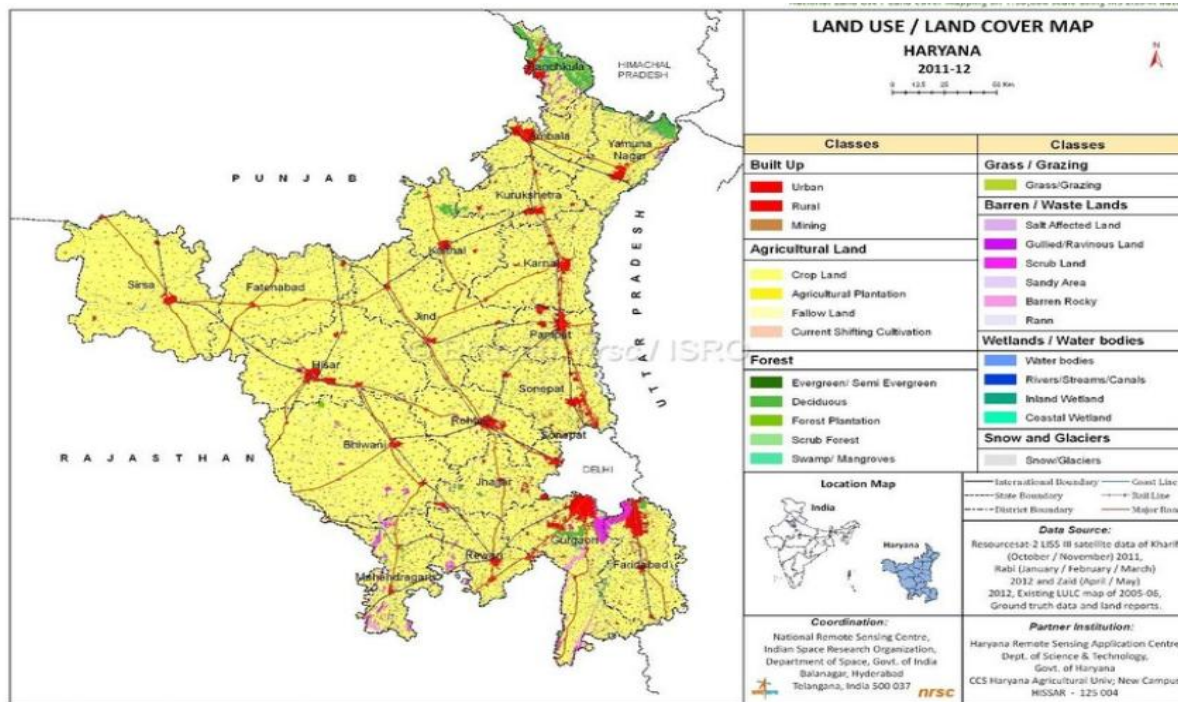


Figure 2: Location of data sites on Haryana map used in model.



Table 1. Geographical parameters of data stations

St.No.	Latitude (Degree)	Longitude (Degree)	Altitude (Meter)
1	18.66	78.1	381
2	18.05	78.26	472
3	18.76	79.43	160
4	18.01	79.56	269
5	18.33	84.13	7
6	17.45	78.46	535
7	17	79.25	227
8	17.66	80.83	54
9	17.25	80.15	112
10	17.35	82.55	19
11	17.68	83.3	70
12	16.75	78	505
13	16.56	79.55	106
14	16.51	80.61	27
15	16.78	80.28	57
16	16.83	81.58	16
17	16.43	81.7	9
18	15.15	76.85	449
19	15.46	78.48	215
20	15.8	78.06	289
21	15.9	80.46	10
22	15.48	80.08	22
23	14.58	77.63	372
24	14.48	78.83	130
25	14.91	80	22
26	14.45	79.98	21
27	13.53	78.5	701
28	13.66	79.58	105

It is clear that all of the stations are spread out among the states. To find the ideal ANN model, three distinct ANN models are created. To determine the parameter that has the greatest influence on how precisely wind speed can be predicted, a parametric analysis has been conducted. Each model requires five pieces of information as input: the month of the year, one of

three climatic variables (P, T, or RH), and each location's latitude, longitude, and altitude. The wind speed is the result for all three of these models. Consequently, each input data set has five data, each of which is connected to one output.

4. DATA ANALYSIS

The creation of an artificial neural network (ANN) model to forecast the solar energy potential in Haryana is presented in this chapter. MATLAB was used to study generalised Feed-forward with Back-Propagation Neural Networks (FBPNN). The design and evaluation of a three-layered neural network with various designs. The mean solar radiation was employed as the network's output, while geographical factors like latitude, longitude, and altitude, as well as meteorological parameters like temperature, sunshine length, relative humidity, and precipitation, were used as input data. Details of data gathering and analysis are presented in the first section. The creation and improvement of ANN for solar radiation prediction is then covered. The mapping of sun radiation over Haryana using a GIS technique comes next. Using these maps, it is possible to locate areas with a greater solar potential. Finally, a remote sensing map is used to determine the appropriate land area that is available in the area with the highest solar potential for the installation of PV panels.

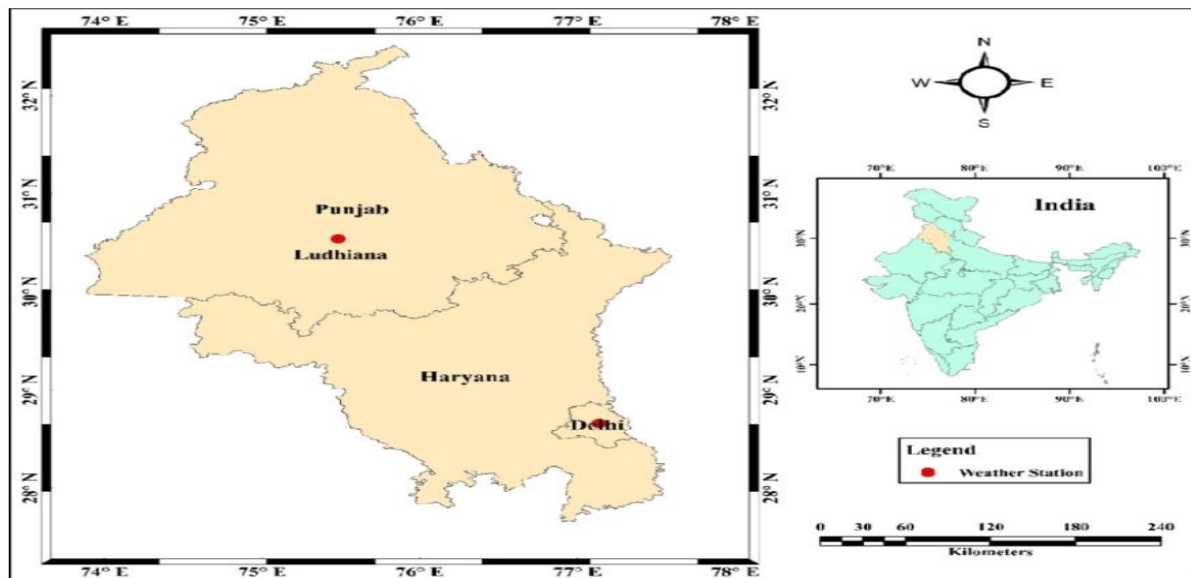


Figure 3: Locations of the stations on Haryana map used to develop ANN model.



28 locations in Haryana with intervals of one degree in latitude and one degree in longitude were taken into consideration for creating the ANN model. For the 22-year period (1983-2005), meteorological data were gathered from the NASA geo-satellite database for all necessary areas, as stated in Appendix-IV. The model was developed taking into account five meteorological factors: temperature, sunshine length, relative humidity, precipitation, and solar radiation. These five factors were measured as monthly means over a 22-year period at 28 different locations. As a result, there are 28 stations, each with 1,320 data values, for a total of 36,960 data values. Three sets of data with 20, 4, and 3 sites each were created. The model was trained using the first data set of 20 locations, validated using the second data set of 4 locations, and checked for accuracy using the third data set of 4 locations. Each place has a full year's worth of weather information. Latitude, longitude, altitude, month, and four meteorological variables—mean temperature, mean sunshine duration, mean relative humidity, and mean precipitation—combine to make up each input data set for the model. Each input data set contained a total of eight values, each of which matched a single output—solar radiation. As a result, 288 data sets were used to train the model, validate it, and test it using 48 data sets. Eight inputs and one output make up each data set, for a total of nine data values. Data for the test location was isolated from training and validation data used to create the model in order to assess the model's predictive power at fresh locations. Figure 2 shows the geographical map of Haryana along with the locations of the stations where the data was collected. Table 2 provides the geographic characteristics of these stations.

Table 2: Geographical parameters of data stations

Sr.No.	Latitude (Degree)	Longitude (Degree)	Altitude (Meter)
1	19.5	78.5	345
2	19.5	79.5	293
3	18.5	77.5	461
4	18.5	78.5	390
5	18.5	79.5	298
6	18.5	80.5	287
7	18.5	82.5	461
8	18.5	83.5	264
9	18.5	84.5	113
10	17.5	77.5	479
11	17.5	78.5	406
12	17.5	79.5	277
13	17.5	80.5	197
14	17.5	81.5	199
15	17.5	82.5	418
16	16.5	77.5	433
17	16.5	78.5	366
18	16.5	79.5	219
19	16.5	80.5	107
20	16.5	81.5	67
21	15.5	77.5	418
22	15.5	78.5	327
23	15.5	79.5	173
24	14.5	77.5	514
25	14.5	78.5	374
26	14.5	79.5	183
27	13.5	78.5	466
28	13.5	79.5	224

The table offers a thorough dataset with different geographic and altitude data for a collection of 28 places. The table has three primary columns: "Latitude (Degree)," "Longitude (Degree)," and "Altitude (Metre)." Each location is identifiable by a distinct "Sr. No." Certain factors are essential for determining the potential for solar energy in certain areas. The amount of solar radiation a region receives is significantly influenced by the "Latitude (Degree)" column, which details the angular distance north or south of the equator for each location. In comparison to



lower latitudes, higher latitudes typically receive less direct sunshine. The "Longitude (Degree)" column indicates the angular separation east or west of the Prime Meridian, which affects when the sun is at its zenith and how long you will be exposed to sunlight. The height or elevation above sea level for each site is given in the "Altitude (Metre)" column. Because greater elevations might result in less atmospheric absorption and scattering of sunlight, altitude is an important consideration in the evaluation of solar energy potential. This dataset contains crucial geographic and altitude factors required to estimate solar radiation, making it appear essential for creating a solar energy forecast model. In order to optimise the installation of photovoltaic (PV) panels for solar energy generation, latitude, longitude, and altitude data can be used to locate areas with the maximum solar potential. Researchers may make educated conclusions about the viability of various areas for utilising solar energy by examining this data.

5. CONCLUSION

The extensive geographic information described in this paper, titled "Geographic Insights into Energy Transition: Renewable Energy Potential in Haryana," illuminates the region of Haryana's astounding potential for the production of renewable energy. The dataset serves as the basis for evaluating and forecasting Haryana's solar energy potential because it contains latitude, longitude, and altitude data for 28 different places. The latitude information tells how each site is situated geographically with respect to the equator, which affects the quantity and intensity of solar energy received. Since direct and constant sunshine is more common at lower latitudes, those regions are excellent possibilities for solar energy harvesting. Higher latitudes, on the other hand, might have seasonal fluctuations in their sun exposure. The east-west positioning of these locales, shown by the longitude information, affects when sunlight is exposed. This factor is crucial for maximising energy production since it affects how solar panels are positioned and oriented to catch the most sunlight. Additionally, the height information, which indicates the elevation above sea level, is very important for evaluating solar energy. Because there is less atmospheric hindrance at higher altitudes, there is more potential for solar energy. These regional insights taken as a whole offer helpful direction for Haryana's planning and adoption of renewable energy sources. Policymakers, energy specialists, and investors can strategically



pinpoint areas with the greatest potential for solar energy by utilising this dataset. This then makes it easier to build solar equipment strategically, making a substantial contribution to the on-going energy transition and the long-term sustainability of Haryana's energy landscape. Understanding and utilising such spatial data is becoming increasingly important for a greener and more sustainable future in Haryana and beyond as renewable energy sources continue to gain significance in addressing climate change and energy security.

REFERENCES

1. Fragkos, K., Fragkos, D., & Kousaridas, S. (2021). A comprehensive survey on the internet of things (IoT) security. *Journal of Network and Computer Applications*, 176, 102913.
2. Godil, M. A., Khan, S., & Latif, S. (2021). A survey on the internet of things (IoT): security architecture and challenges. *IEEE Internet of Things Journal*, 8(19).
3. Gulagi, S., Agarwal, S., & Kumar, V. (2017). A survey on natural language generation for dialogue systems.
4. Gulagi, S., Agarwal, S., & Kumar, V. (2018). A survey on natural language generation for task-oriented dialogue systems.
5. Jain, A., Sharma, R., & Gupta, S. (2020). A survey on natural language generation for factual language models. *arXiv preprint*.
6. Jain, S., Jain, N., & Jain, S. (2021). A survey on security architecture for internet of things (IoT). *Journal of Information Security and Applications*, 55, 102578.
7. Kumar, K., Kumar, V., & Gupta, S. (2020). A survey on natural language generation for chatbots in customer service. *arXiv preprint arXiv:2002.09506*.
8. Moallemi, M., Ebrahimi, M., & Farhadi, H. (2017). A review of natural language generation for chatbots. *arXiv preprint arXiv:1707.05862*.
9. Pandey, A., & Sharma, S. (2021). A survey on security challenges and solutions in internet of things (IoT). *International Journal of Communication Systems*.