

Spatial Distribution and Growth of Renewable Energy Sources in Karnataka: A Geographical Analysis

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Abstract

Renewable energy has emerged as an important component of Karnataka's energy system, contributing to energy security, environmental sustainability and regional economic development. Karnataka possesses considerable potential for solar, wind, hydropower, biomass and other renewable energy resources because of its varied physical geography, high solar radiation, extensive plateau regions, favourable wind corridors, and agricultural base and river systems. The present study examines the spatial distribution and growth of renewable energy sources in Karnataka from a geographical perspective. Particular attention is given to solar, wind, small hydro, biomass and co-generation, together with the regional factors influencing their distribution. As of 31 March 2025, Karnataka had about 23.92 GW of renewable-energy installed capacity and ranked fourth in India in renewable-energy installed capacity. Solar constituted 47.85 per cent of the state's renewable-energy capacity, while wind accounted for 36.34 per cent. Renewable energy contributed 48.10 per cent of Karnataka's total electricity generation during 2024–25.

The exponential growth model indicates a statistically significant positive trend in Karnataka's renewable energy capacity during 2014–15 to 2024–25. The model recorded an R^2 value of 0.834, an F -value of 45.158, and a p -value of 0.000 ($p < 0.001$). The data further show that total renewable energy capacity increased from 5,199.71 MW in 2014–15 to 20,228.44 MW in 2024–25, representing an increase of 15,028.73 MW. The particularly rapid expansion after 2016–17, especially with the growth of solar and wind power, contributed substantially to this overall upward trend. Since, the p -value is less than the 0.05 significance level, the null hypothesis is rejected, and the alternative hypothesis is accepted. Therefore, it is concluded that there has been a statistically significant increase in renewable energy capacity in Karnataka during the study period. The increase from 5,199.71 MW in 2014–15 to 20,228.44 MW in 2024–25, along with an estimated exponential growth rate of approximately 13.92% per annum, provides further evidence of the strong expansion of renewable energy in the state.

Keywords: Renewable Energy; Karnataka; Spatial Distribution; Solar Energy; Wind Energy; Hydropower; Trend Analysis; Exponential Growth Model and Geographical Analysis.

Introduction

Energy is a fundamental requirement for economic development, industrialisation, urbanisation and improvement in the quality of life. Rapid economic growth, population expansion and increasing electricity demand have created pressure on conventional energy resources. The environmental consequences associated with fossil fuels, including greenhouse-gas emissions, air pollution and climate change, have further increased the importance of renewable energy. Renewable energy sources such as solar, wind, hydropower, biomass and waste-to-energy provide alternatives to conventional fossil-fuel-based energy. Their development is not uniform across geographical space.

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Physical factors such as climate, topography, solar radiation, wind velocity, drainage systems and availability of land interact with human factors such as population density, infrastructure, investment, government policy and electricity demand.

Karnataka occupies a particularly important position in India's renewable-energy landscape. The state has a combination of high solar radiation, extensive dry-land areas, favourable wind corridors, river systems and substantial agricultural and industrial biomass resources. These geographical characteristics have enabled Karnataka to develop a diversified renewable-energy portfolio. According to the Ministry of New and Renewable Energy, Karnataka had 25,675.39 MW of installed renewable-energy capacity as on 31 October 2025, representing approximately 10.24 per cent of India's total installed renewable-energy capacity. Earlier official assessment for 31 March 2025 placed Karnataka's renewable installed capacity at 23.92 GW, making it the fourth-ranked state in India. Renewable energy accounted for 68.98 per cent of the state's total installed electricity capacity in 2024–25.

The geographical distribution of renewable energy in Karnataka, however, is highly differentiated. Solar-energy development is particularly concentrated in the central and northern dry regions, while wind projects are concentrated in areas with favourable wind regimes. Hydropower is associated mainly with the Western Ghats and major river systems. Biomass and co-generation are closely related to agricultural production and agro-industrial activities.

Objectives of the Study

1. To study the performance and growth in trends of renewable energy sources in Karnataka.
2. The present study examines the spatial distribution and growth of renewable energy sources in Karnataka from a geographical perspective.

Hypothesis

1. There is a significant increase in renewable energy capacity in Karnataka during the study period.

Materials and Method

The study is based on secondary data collected from various government and institutional sources, including the Ministry of New and Renewable Energy (MNRE), Ministry of Power, Government of India, NABARD, and the Central Electricity Authority (CEA). State-level information was obtained from Karnataka Renewable Energy Development Limited (KREDL), the Energy Department, Government of Karnataka, the Karnataka Economic Survey (2025), and the Directorate of Economics and Statistics (2025). Additional information was sourced from other government publications, research journals, scholarly articles, newspapers, magazines, and reliable websites. For the systematic analysis and interpretation of the data, the study employed statistical techniques such as percentage analysis, growth-rate analysis, Compound Annual Growth Rate (CAGR), exponential growth modelling, source-wise comparison, spatial interpretation, and trend analysis. The data were processed and analysed using Microsoft Excel, SPSS 21, EVIEWS, and Gretl.

Performance of Renewable Energy Sources in Karnataka

Karnataka is a leading state in India for green power, with renewable sources making up over 60% of its total energy capacity. As of late 2025, the state's total grid-connected renewable capacity reached approximately 25.8 GW, solidifying its rank among India's top five clean energy producers. Karnataka has emerged as one of India's leading states in renewable energy development, supported by favourable climatic conditions, abundant solar and wind resources, and progressive government policies. As of 31 October 2025, Karnataka had a total installed renewable energy capacity of 25,675.39 MW, accounting for approximately 10.24 per cent of India's total renewable energy capacity. Among the various renewable energy sources, solar energy has emerged as the major contributor to Karnataka's renewable energy portfolio. In October 2025, solar power accounted for 10,592.12 MW, including ground-mounted, rooftop, off-grid and hybrid installations. The state's extensive solar potential has been effectively

utilised through large-scale solar parks, particularly the Pavagada Solar Park, as well as rooftop and distributed solar projects. Wind energy is another important component, with an installed capacity of 8,193.29 MW in 2025.

Karnataka's favourable wind conditions, particularly in the northern and central districts, have supported substantial investment in wind power. Large hydropower contributed about 3,689.20 MW, while small hydropower contributed 1,284.73 MW. Bioenergy also made a significant contribution, with approximately 1,916.05 MW, reflecting the importance of agricultural residues and cogeneration in the state's renewable energy mix. The performance of renewable energy has also been strengthened by increasing capacity additions. The Karnataka Economic Survey (2024) reported 637.98 MW of renewable capacity addition during 2024–25 up to December 2024, of which solar accounted for 465.45 MW and wind 131.33 MW.

Table -1 Source-wise Renewable Energy Installed Capacity in Karnataka, 2026

Sl. No.	Renewable Energy Source	Installed Capacity (MW)
1	Small Hydro Power	1,284.73
2	Wind Power	8,423.64
3	Biomass Power/Bagasse Cogeneration	1,868.91
4	Biomass Cogeneration (Non-Bagasse)	20.20
5	Waste-to-Energy	1.00
6	Waste-to-Energy (Off-grid)	26.94
	Bio-Power Total	1,917.05
1	Ground-Mounted Solar	9,758.44
2	Rooftop Solar (including PM-Surya Ghar Yojana)	809.20
3	Hybrid Solar Component	212.25
4	Off-grid Solar/KUSUM Component-B	44.11
	Solar Power Total	10,824.00
1	Large Hydro	3,689.20
	Total Renewable Energy Capacity	26,138.62

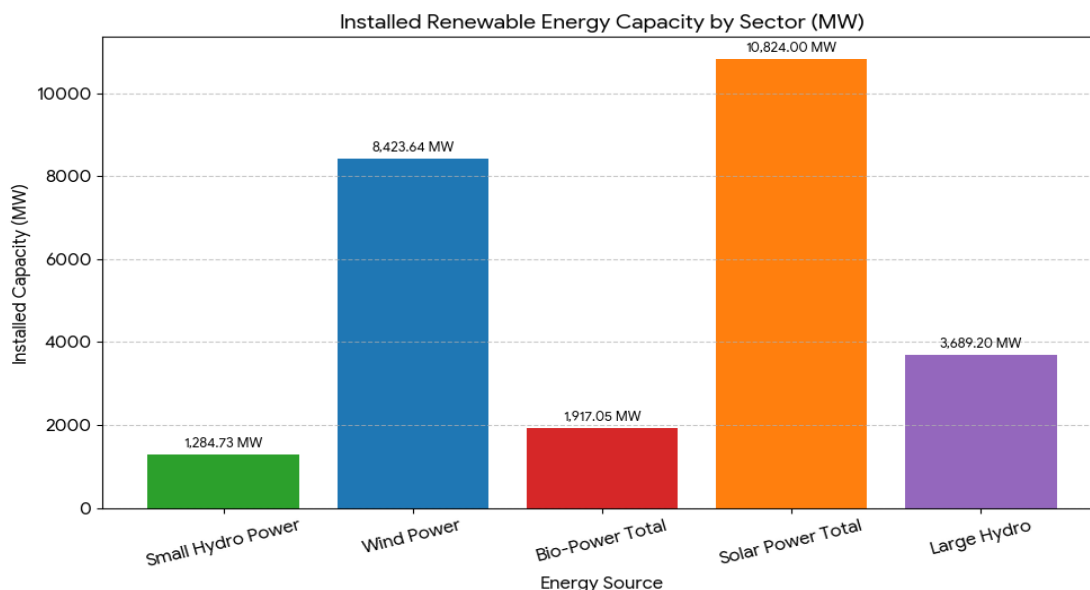
Source: Ministry of New and Renewable Energy (MNRE), State-wise (Location based) Installed Capacity of Renewable Power as on 31.01.2026.

As shown in the table, the solar sector recorded the highest installed capacity in Karnataka at 10,824 MW, followed by wind power (8,423.64 MW). Large hydro contributed 3,689.20 MW, while bio-power and small hydro accounted for 1,917.05 MW and 1,284.73 MW, respectively. Thus, solar and wind together accounted for about 73.6% of Karnataka's total renewable-energy capacity, highlighting the increasing importance of solar and wind resources in the state's renewable-energy transition.

Table -2 Renewable Source-wise Installed Capacity and Share in Karnataka, 2026

Sl. No.	Renewable Energy Source	Installed Capacity (MW)	Total Share of %
1	Solar Power	10,824.00	41.41
2	Wind Power	8,423.64	32.23
3	Large Hydro	3,689.20	14.11
4	Bio-Power	1,917.05	7.33
5	Small Hydro Power	1,284.73	4.92
	Total	26,138.62	100.00

Source: Compiled Data by the Researcher



Results and Discussion

Trends in Renewable Energy Capacity in Karnataka: A Trend Analysis

This study analysed that the trends in Renewable Energy Capacity in Karnataka. The Karnataka Government, through the implementation of the Karnataka Renewable Energy Policy 2022–27 and under the leadership of the KREDL, has accelerated private investment in renewable energy. As a result, renewable energy capacity additions reached 1,209.19 MW in 2024–25 and 1,762.64 MW in 2025–26 (up to December), as per the Economic Survey of Karnataka (2025).

Table-3: Source-wise Renewable Energy Installed Capacity in Karnataka, (2015 to 2025)

(In MW)

Year	Small Hydro Power	Wind Power	Bio-Power	Solar Power	Total Renewable Energy
2014–15	1,105.73	2,638.20	1,371.83	83.95	5,199.71
2015–16	1,217.73	2,869.10	1,427.83	158.41	5,673.07
2016–17	1,225.73	3,751.40	1,477.83	1,045.30	7,500.26
2017–18	1,230.73	4,608.40	1,779.81	4,965.25	12,584.19
2018–19	1,254.73	4,694.90	1,809.81	6,120.76	13,880.20
2019–20	1,280.73	4,790.60	1,896.42	7,306.18	15,273.93
2020–21	1,280.73	4,938.60	1,901.92	7,383.88	15,505.13
2021–22	1,280.73	5,130.90	1,902.15	7,590.81	15,904.59
2022–23	1,280.73	5,294.95	1,902.15	8,241.40	16,719.23
2023–24	1,280.73	6,019.61	1,907.72	8,544.68	17,752.74
2024–25	1,284.73	7,351.10	1,912.95	9,679.66	20,228.44

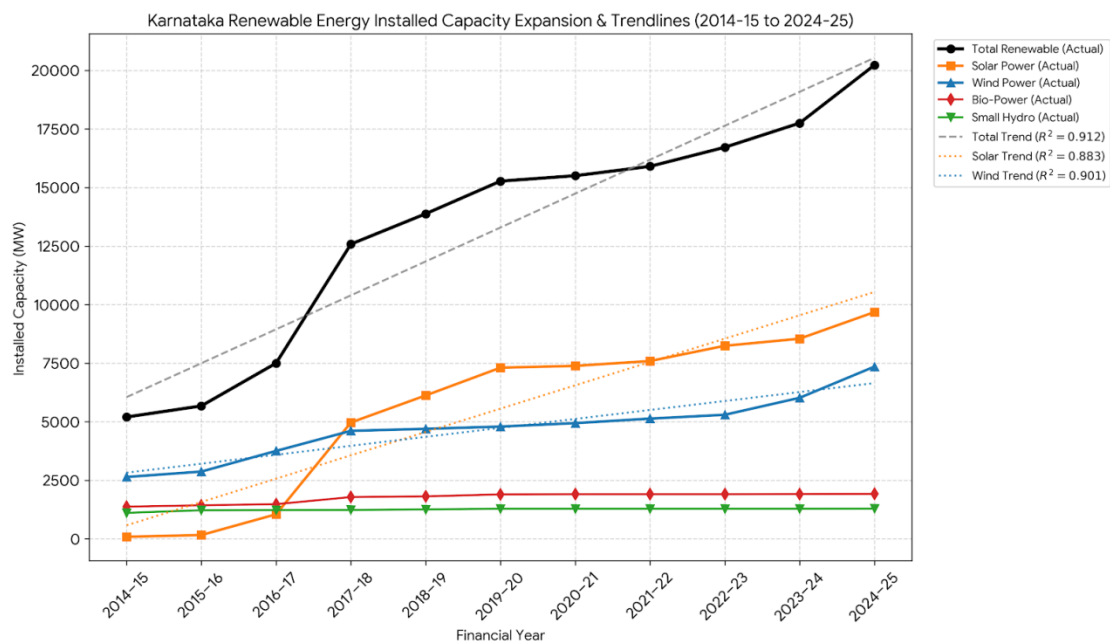
Source: Ministry of New and Renewable Energy (MNRE), Renewable Energy Statistics 2024–25.

Note: The year 2015–16 means capacity as on 31 March 2016, 2016–17 means capacity as on 31 March 2017, and so on. MNRE reports national/state installed-capacity data on a financial-year basis (April–March).

The table presents the source-wise installed renewable energy capacity in Karnataka from 2014–15 to 2024–25. The data clearly indicate a substantial expansion of renewable-energy capacity, accompanied by a major structural shift from conventional renewable sources such as small hydro towards solar and wind energy. The total installed capacity of the four renewable-energy sources increased from 5,199.71 MW in 2014–15 to 20,228.44 MW in 2024–

25, representing an increase of about 289.03 per cent over the study period. The corresponding CAGR was approximately 14.55 per cent. The growth was particularly rapid during 2016–17 to 2017–18, when total capacity increased from 7,500.26 MW to 12,584.19 MW.

Solar energy recorded the highest growth among all renewable sources. Its installed capacity increased dramatically from only 83.95 MW in 2014–15 to 9,679.66 MW in 2024–25. This represents an increase of more than 11,430 per cent, with a CAGR of approximately 60.76 per cent. The most significant expansion occurred between 2016–17 and 2017–18, when solar capacity increased from 1,045.30 MW to 4,965.25 MW. By 2024–25, solar accounted for approximately 47.85 per cent of the renewable capacity represented in the table. Thus, solar energy emerged as the dominant renewable-energy source in Karnataka.



Wind power showed a strong and relatively consistent upward trend. Its capacity increased from 2,638.20 MW in 2014–15 to 7,351.10 MW in 2024–25, an increase of approximately 178.64 per cent. The CAGR was 10.79 per cent. Growth was particularly noticeable after 2015–16 and again during 2023–24 to 2024–25. Wind power represented about 36.34 per cent of the renewable capacity in 2024–25, making it the second-largest source after solar. Bio-power experienced moderate growth during the study period. Capacity increased from 1,371.83 MW in 2014–15 to 1,912.95 MW in 2024–25, an increase of about 39.45 per cent, with a CAGR of 3.38 per cent. The growth was relatively gradual compared with solar and wind. Bio-power accounted for around 9.46 per cent of total capacity in 2024–25. Its development reflects Karnataka's agricultural base and availability of agricultural and agro-industrial residues.

Small hydropower recorded the slowest growth among the four sources. Capacity increased from 1,105.73 MW in 2014–15 to 1,284.73 MW in 2024–25, representing an increase of only 16.19 per cent and a CAGR of approximately 1.51 per cent. Karnataka's total renewable energy capacity expanded from 5,199.71 MW in 2014–15 to 20,228.44 MW in 2024–25, representing a CAGR of 14.55% and an average linear addition of 1,448.95 MW/year.

Table-4: Trend Analysis of Renewable Energy Sources in Karnataka (2014 to 2024)

Renewable Source	2014–15 (MW)	2024–25 (MW)	Increase (%)	CAGR (%)	Share in 2024–25
Small Hydro	1,105.73	1,284.73	16.19	1.51	6.35%
Wind	2,638.20	7,351.10	178.64	10.79	36.34%
Bio-Power	1,371.83	1,912.95	39.45	3.38	9.46%
Solar	83.95	9,679.66	11,430.27	60.76	47.85%
Total	5,199.71	20,228.44	289.03	14.55	100.00%

Source: Compiled Data by the Researcher

Table-5: Growth and Trend of Renewable Energy Capacity in Karnataka (2014–15 to 2024–25)

(In MW)

Sources	2014–15	2024–25	Net Addition	CAGR (%)	Linear Slope (m) (MW/year)	Fit Reliability (R ²)	Linear Trend Equation
Solar Power	83.95	9,679.66	+9,595.71	60.76	+996.60	0.883	Capacity = 996.60t + 573.38
Wind Power	2,638.20	7,351.10	+4,712.90	10.79	+382.60	0.901	Capacity = 382.60t + 2,822.26
Bio-Power	1,371.83	1,912.95	+541.12	3.38	+56.68	0.756	Capacity = 56.68t + 1,470.27
Small Hydro	1,105.73	1,284.73	+179.00	1.51	+13.07	0.655	Capacity = 13.07t + 1,182.18
Total	5,199.71	20,228.44	+15,028.73	14.55	+1,448.95	0.912	Capacity = 1,448.95t + 6,048.09

Source: Compiled Data by the Researcher

Note: CAGR = Compound Annual Growth Rate; m = annual linear growth in MW; R² = coefficient of determination indicating the reliability of the linear trend fit; t = time period.

Spatial Distribution of Renewable Energy Sources in Karnataka: A Geographical Analysis

This section analyses the spatial distribution of renewable energy sources in Karnataka. It is characterised by considerable geographical variation due to differences in solar radiation, wind regimes, topography, water availability, agricultural resources, and land-use conditions. The state has developed a diversified renewable energy portfolio, with solar and wind energy emerging as the dominant sources. Solar power has the widest geographical potential and has become the leading renewable energy source in Karnataka. Its concentration is particularly notable in the eastern and northern dry zones, where high solar radiation, relatively low rainfall and extensive areas of suitable land favour large-scale solar projects. Major development has occurred in districts such as Tumakuru, Koppal, Ballari, Vijayapura, Kalaburagi, Raichur and Chitradurga. The Pavagada Solar Park in Tumakuru district represents one of the most significant examples of large-scale solar development in the state.

As of 2025, the state had an installed renewable energy capacity of 25,675.39 MW, accounting for approximately 10.24% of India's total installed renewable energy capacity of 2,50,643.45 MW. Karnataka is one of the leading states in renewable energy generation, with significant contributions from solar, wind, hydropower, biomass, and other renewable sources. The figure below illustrates the location and spatial distribution of renewable energy installations by source across Karnataka during 2025–2026, highlighting the geographical concentration of different renewable energy resources within the state.

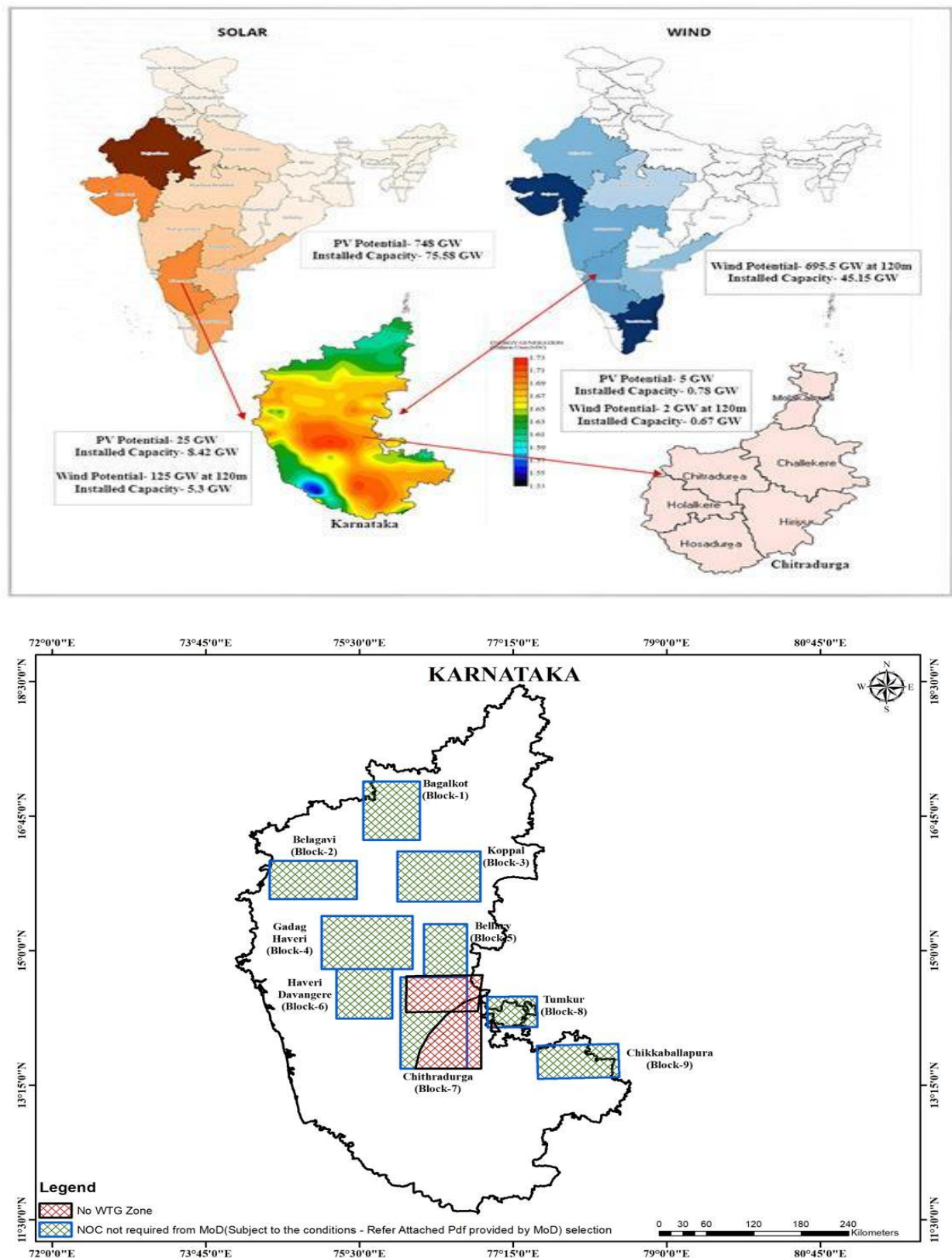
Wind power is mainly concentrated in areas with favourable wind speeds, particularly along the Deccan Plateau and elevated terrain of northern, central and southern Karnataka. Important wind-energy districts include Chitradurga, Gadag, Davanagere, Ballari, Koppal, Bagalkot, Vijayapura and Tumakuru. The geographical distribution of wind projects reflects the importance of elevation, terrain and seasonal wind patterns. Large hydropower is spatially concentrated along the major river systems, particularly the Sharavathi, Krishna, Cauvery and their tributaries. The Western Ghats and Malnad region provide favourable topographical conditions for hydropower generation because of high rainfall, steep gradients and perennial or seasonal river flows. Major hydropower development is therefore associated with districts such as Shivamogga, Uttara Kannada, Chikkamagaluru, Kodagu and Mysuru.

Table –6 Spatial Distribution on Renewable Energy Sources in Karnataka - 2026

Renewable Energy Source	Major Districts	Spatial Distribution
Solar Energy	Tumakuru (Pavagada), Ballari, Koppal, Raichur, Chitradurga, Vijayapura	Highest concentration in the dry northern and central districts with high solar radiation.
Wind Energy	Chitradurga, Gadag, Ballari, Vijayapura, Davanagere, Belagavi	Concentrated in central and northern Karnataka where wind corridors are strong.
Hydropower	Shivamogga, Uttara Kannada, Kodagu, Chikkamagaluru, Hassan	Located in the Western Ghats due to high rainfall and perennial rivers such as Sharavathi and Kali.
Biomass Energy	Mandya, Belagavi, Hassan, Bagalkot, Mysuru	Found in agricultural regions with abundant sugarcane, rice husk, and other crop residues.
Waste-to-Energy/Biogas	Bengaluru, Mysuru, Hubballi-Dharwad	Urban centers generating municipal solid waste and organic waste.

Source: Government of Karnataka (2025), Energy Development, Karnataka Renewable Energy Policy 2022-27

Small hydropower projects are similarly associated with hilly and water-rich areas, especially the Western Ghats and Malnad region. Their distribution is more dispersed than large hydropower projects and is influenced by the availability of small rivers, streams and suitable elevation differences. Bio-power has a distinctive agricultural and agro-industrial spatial pattern. It is concentrated in districts producing substantial quantities of sugarcane, rice, coconut and other agricultural residues. Consequently, districts such as Mandya, Belagavi, Bagalkot, Vijayapura, Davanagere, Mysuru and Shivamogga provide favourable conditions for biomass-based power generation.

Figure: Spatial Distribution Section with a Karnataka Renewable-Energy Map**Figure: 1.2 Solar Distributions**

Source: Compiled from KREDL, Karnataka Economic Survey, Government of Karnataka, MNRE and GIS-based renewable-energy resource studies.

The spatial distribution of renewable energy resources in Karnataka demonstrates considerable geographical variation, reflecting differences in solar radiation, wind velocity, topography, rainfall, river systems, agricultural production and availability of land. The state's renewable-energy landscape is broadly characterised by the concentration of solar and wind power in the dry interior regions, hydropower in the Western Ghats and Malnad region, and bio-power in agriculturally productive areas.

Solar energy has the broadest spatial distribution and has become the dominant renewable energy source. The dry and semi-arid districts of central and northern Karnataka provide favourable conditions for large-scale solar projects. Tumakuru, Chitradurga, Koppal, Ballari, Raichur, Vijayapura, Kalaburagi and surrounding districts have significant solar development. The Pavagada Solar Park in Tumakuru is a major example of large-scale solar development. District-level solar-resource mapping also demonstrates substantial variation in solar potential across Karnataka.

Wind energy is concentrated mainly in areas with favourable wind speeds and suitable terrain. Important wind-energy regions include Chitradurga, Tumakuru, Davanagere, Gadag, Koppal, Ballari, Bagalkot and Vijayapura. Earlier GIS-based studies have identified significant seasonal variation in wind resources across Karnataka, while recent KREDL initiatives have further emphasised taluk-wise wind-potential mapping for renewable-energy planning.

Hydropower shows a distinctly different spatial pattern. Large and small hydro projects are concentrated in the Western Ghats and Malnad areas, particularly in districts such as Shivamogga, Uttara Kannada, Chikkamagaluru, Kodagu and Mysuru, where steep terrain and water availability provide favourable conditions. GIS-based studies have also demonstrated district- and taluk-level variations in small-hydro potential.

Bio-power is closely associated with agricultural and agro-industrial regions because of the availability of crop residues, sugarcane bagasse and other biomass resources. Thus, districts with substantial agricultural and sugar-industry activity have greater potential for biomass and cogeneration projects.

PM Surya Ghar Muft Bijli Yojana (PMSG: MBY) is a demand driven scheme for installation of rooftop solar (RTS) systems, wherein all residential consumers in the country having grid connected electricity connection of the local DISCOM can avail the benefits of the scheme by applying on the National Portal of the scheme. As on 26.11.2025, a total of 18,72,499 RTS systems have been installed, benefitting 23,47,694 households, under the scheme across the country. Out of these, a total of 14,151 RTS systems have been installed, benefitting 22,313 households, in the state of Karnataka. In the Belagavi district of Karnataka, a total of 25,778 applications have been submitted on the National Portal and 681 households have been benefitting with installations of rooftop solar under the scheme as on 26.11.2025.

Hypothesis Testing

H0: There is no significant increase in renewable energy capacity in Karnataka during the study period.

H1: There is a significant increase in renewable energy capacity in Karnataka during the study period.

Table-7 Exponential Growth Model for Total Renewable Energy Capacity in Karnataka

S. No	Variables	Exponential Growth Model Result
1	Constant (a)	5,570.61
2	Growth Coefficient (b)	0.1304
3	Annual Exponential Growth Rate	13.92%
4	R ²	0.834
5	F-value	45.158
6	Significance (p-value)	0.000
7	Exponential Trend Equation	$Y = 5,570.61e^{0.1304t}$

The exponential growth model indicates a statistically significant positive trend in Karnataka's renewable energy capacity during 2014–15 to 2024–25. The model recorded an R^2 value of 0.834, an F -value of 45.158, and a p -value of 0.000 ($p < 0.001$). The data further show that total renewable energy capacity increased from 5,199.71 MW in 2014–15 to 20,228.44 MW in 2024–25, representing an increase of 15,028.73 MW. The particularly rapid expansion after 2016–17, especially with the growth of solar and wind power, contributed substantially to this overall upward trend. Since, the p -value is less than the 0.05 significance level, the null hypothesis is rejected, and the alternative hypothesis is accepted. Therefore, it is concluded that there has been a statistically significant increase in renewable energy capacity in Karnataka during the study period. The increase from 5,199.71 MW in 2014–15 to 20,228.44 MW in 2024–25, along with an estimated exponential growth rate of approximately 13.92% per annum, provides further evidence of the strong expansion of renewable energy in the state.

Concluding Remarks

The study “Spatial Distribution and Growth of Renewable Energy Sources in Karnataka: A Geographical Analysis” concludes that Karnataka has made significant progress in renewable-energy development and has emerged as an important renewable-energy-producing state in India. The total installed renewable-energy capacity reached 26,138.62 MW in 2026, demonstrating the strong expansion of the sector. The data reveal that solar power is the leading renewable source, with 10,824.00 MW, representing 41.41 per cent of the total capacity. Wind power ranks second with 8,423.64 MW (32.23 per cent). Together, solar and wind account for 73.64 per cent of Karnataka's renewable-energy capacity. Large hydropower contributes 3,689.20 MW (14.11 per cent), followed by bio-power with 1,917.05 MW (7.33 per cent) and small hydropower with 1,284.73 MW (4.92 per cent). The growth pattern indicates that solar energy has experienced the most rapid expansion, particularly after 2016–17, while wind energy has maintained steady growth. Bio-power has increased gradually, whereas small hydropower has shown relatively limited growth. Consequently, the overall expansion of renewable energy in Karnataka has been largely driven by solar and wind power.

The geographical analysis shows a distinct spatial pattern. Solar and wind energy are concentrated mainly in the dry and semi-arid regions of northern, central and eastern Karnataka, while hydropower is concentrated in the Western Ghats and Malnad regions due to favourable rainfall, river systems and topography. Bio-power is associated mainly with agriculturally productive and agro-industrial districts.

Finally, Karnataka possesses a diverse renewable-energy resource base with considerable future potential. The findings emphasise the need for region-specific renewable-energy planning, improved transmission networks, energy-storage systems and sustainable land management. Continued investment and effective government policies can enable Karnataka to further strengthen its renewable-energy capacity and contribute to energy security, environmental sustainability, climate resilience and sustainable economic development.

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