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ENERGY CONSUMPTION IN KARNATAKA: INSIGHTS INTO CURRENT TRENDS AND FUTURE DIRECTIONS

Mouneshwari G[1], H H Bharadi[2]
[1]*PhD Research Scholar, Department of Studies in Economics, Karnatak University, Dharwad. Karnataka State, India.*
[2]*Senior Professor and Chairman, Department of Studies in Economics, Karnatak University, Dharwad. Karnataka State, India.*

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ABSTRACT
This study examines Karnataka's energy consumption patterns and projections to provide a comprehensive understanding of its current and future energy landscape. Karnataka, a rapidly developing state in India, has experienced significant changes in energy demand driven by factors such as population growth, urbanization, and industrialization. The analysis reveals a complex energy mix for 2023-24, with coal remaining the dominant source of power, while substantial investments are being made in renewable energy sources like solar and wind. The study also highlights fluctuations in per capita power availability and overall power availability, reflecting challenges in sustaining long-term growth in power supply. Projections for energy consumption and peak demand up to 2031-32 indicate a steady increase, necessitating strategic planning and industrialization. development to accommodate rising demands. The review of literature underscores the importance of energy efficiency, renewable energy adoption, and policy frameworks in shaping Karnataka's energy future. This study aims to provide insights into both current trends and future directions, emphasizing the need for balanced energy strategies to support the state's ongoing growth and development.

KEYWORDS: *consumption, demand, industrialization., industrialization., growth and development.*

INTRODUCTION
Karnataka, one of India's most dynamic and rapidly developing states, has experienced significant changes in its energy consumption patterns over the past few decades. With its diverse economy, ranging from agriculture and manufacturing to IT and services, the state has seen a steady rise in energy demand. The current energy landscape in Karnataka reflects the interplay of various factors, including population growth, urbanization, industrialization, and technological advancements.

As Karnataka continues to progress, understanding its energy consumption trends is crucial for planning sustainable energy policies and meeting future demands. This study delves into the present energy consumption patterns in Karnataka, examining key sectors such as residential, commercial, industrial, and agricultural. Additionally, it explores future directions by considering factors like energy efficiency, the transition to renewable energy sources, and the impact of emerging technologies.

By providing insights into both current trends and future scenarios, this study aims to offer a comprehensive understanding of Karnataka's energy landscape, highlighting the challenges and opportunities that lie ahead in ensuring a sustainable and reliable energy supply for the state's continued growth and development

REVIEW OF LITERATURE
Several studies have documented the evolving energy consumption patterns in Karnataka, emphasizing the growing demand across various sectors. Research by Ramachandra et al. (2011) analyzed the energy consumption dynamics in Karnataka, highlighting the significant role of the industrial and agricultural sectors. The study found that industrialization and urbanization have been major drivers of energy demand, with electricity being the primary energy source. Similarly, studies at the national level, such as those by Bhattacharyya and Ohiare (2012), have contextualized Karnataka's trends within India's broader energy landscape, illustrating the state's contribution to the overall national energy demand.

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Literature on energy efficiency in Karnataka has focused on the potential for reducing energy consumption through improved practices and technologies. For instance, research by Mathur et al. (2015) explored energy efficiency measures in the industrial sector, noting the significant opportunities for reducing energy intensity. Studies have also examined the role of policy interventions, such as the implementation of the Perform, Achieve, and Trade (PAT) scheme, in enhancing energy efficiency at both the state and national levels (Sharma et al., 2017). These studies underline the importance of energy efficiency in meeting future energy needs while minimizing environmental impacts.

The shift towards renewable energy is a central theme in recent literature on Karnataka's energy future. Reports by the Karnataka Renewable Energy Development Limited (KREDL) and studies like those by Singh and Nambiar (2020) have documented the state's progress in harnessing renewable energy sources, particularly solar and wind. These studies emphasize the state's ambitious targets for renewable energy capacity, driven by favorable policies and the state's geographic advantages. However, challenges such as grid integration, variability in renewable energy generation, and the need for technological advancements are also highlighted.

Emerging technologies, such as smart grids, energy storage, and electric mobility, are increasingly being recognized as key enablers of a sustainable energy future. Literature by Joshi and Rai (2021) discussed the potential of smart grid technologies in Karnataka, emphasizing their role in enhancing grid reliability and accommodating the growing share of renewable energy. Studies on electric mobility, such as those by Kumar and Sharma (2022), have explored the implications of increasing electric vehicle adoption on Karnataka's energy demand and infrastructure.

Policy frameworks play a crucial role in shaping the energy landscape. Research by Singh et al. (2018) analyzed Karnataka's energy policies, particularly in the context of the state's Renewable Energy Policy and Energy Conservation Building Code (ECBC). The study highlighted the importance of integrated energy planning to balance demand and supply, ensure energy security, and promote sustainability. Additionally, the role of central government initiatives, such as the Ujwal DISCOM Assurance Yojana (UDAY), in improving the financial health of state utilities and enhancing energy distribution efficiency, has been a key focus of policy-related literature.

Research on Karnataka's energy consumption has documented the shifts in energy use across different sectors over time. Studies like those by Reddy and Balachandra (2006) provide an early analysis of the state's energy consumption, noting significant growth in the industrial and residential sectors. These studies emphasize the role of economic development in driving energy demand, with a notable shift from traditional biomass to commercial energy sources such as electricity and petroleum products. The Karnataka State Pollution Control Board (KSPCB) reports further elaborate on the environmental implications of these trends, particularly the increased emissions from the industrial sector.

Karnataka's abundant renewable energy resources have been the focus of numerous studies, particularly in the context of India's broader push towards sustainable energy. Research by Gurunathan and Arunachalam (2011) explores the state's potential in solar and wind energy, highlighting the favorable geographic and climatic conditions. The Karnataka Renewable Energy Development Limited (KREDL) has also published various reports on the state's progress in renewable energy capacity addition, especially in wind and solar power. These studies underscore the state's leadership in renewable energy within India but also point to challenges such as grid integration and the intermittency of renewable sources.

Energy efficiency has been identified as a key area for reducing Karnataka's overall energy demand. Studies like those by Somashekar and Mohan (2015) examine the potential for energy savings in the industrial and residential sectors through the adoption of energy-efficient technologies and practices. The Bureau of Energy Efficiency (BEE) and other governmental agencies have also conducted assessments and launched initiatives to promote energy efficiency in Karnataka, particularly in the context of the Perform, Achieve, and Trade (PAT) scheme. However, the literature also highlights barriers such as the high upfront costs of energy-efficient technologies and a lack of awareness among consumers.

Karnataka's energy policies have been a subject of detailed analysis in the literature. Research by Basavaraj and Venkatesh (2019) provides a comprehensive review of the state's energy policies, including the Karnataka Renewable Energy Policy and the Karnataka Solar Policy. These policies have been instrumental in promoting renewable energy and energy efficiency. However, studies also point out the challenges of policy implementation, particularly in rural areas, where energy access and affordability remain significant issues (Singh et al., 2020). The role of central government schemes, such as the Ujwal DISCOM Assurance Yojana (UDAY) and the Deen

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Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY), in supporting Karnataka's energy infrastructure has also been critically examined.

Future-oriented studies provide projections for Karnataka's energy demand, considering factors such as population growth, urbanization, and economic development. The Integrated Energy Policy (IEP) reports by the Planning Commission of India and studies by Bhattacharya et al. (2021) offer insights into potential scenarios for Karnataka's energy future. These studies suggest that while Karnataka is well-positioned to meet future energy demands through a mix of renewable and conventional sources, significant challenges remain. These include the need for substantial investments in energy infrastructure, the integration of renewable energy into the grid, and addressing the social and environmental impacts of energy development.

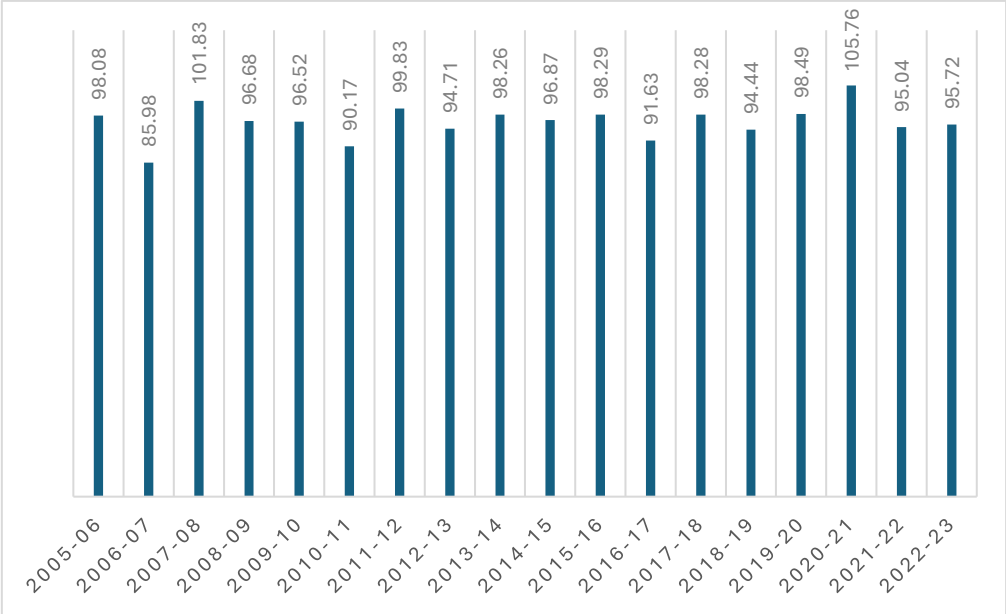
OBJECTIVES OF THE STUDY

- analyze the energy demand and supply situation in Karnataka.
- To study the energy sources and future energy trends in Karnataka

The objectives of this study are to analyze the current energy demand and supply situation in Karnataka, focusing on how well the state's energy needs are being met. It aims to evaluate the various energy sources used, including conventional and renewable options, to understand the state's energy mix. Additionally, the study seeks to explore future energy trends by forecasting energy consumption and peak demand, considering factors like population growth and economic development.

This study utilized the Average Annual Growth Rate (AAGR) to understand the objectives and analyze the energy landscape in Karnataka.

Graph 1. KARNATAKA PER CAPITA AVAILABILITY OF POWER* (Kilowatt-Hour)



Sources: RBI

The data on the per capita availability of power in Karnataka from 2005-06 to 2022-23 highlights several notable trends. Initially, from 2005-06 to 2006-07, there was a sharp decline in power availability, dropping from 98.08 kWh to 85.98 kWh, followed by a significant recovery in 2007-08 to 101.83 kWh. However, the years 2008-09 to 2010-11 saw a slight decline, with values fluctuating between 90.17 and 96.68 kWh, reflecting some instability during this period. The following years, from 2011-12 to 2019-20, were marked by relative stability, with per capita power availability remaining within the 90-99 kWh range, suggesting consistent energy production and supply. The year 2020-21 witnessed a notable increase to 105.76 kWh, the highest in the period, likely influenced by changes in power consumption patterns during the COVID-19 pandemic. However, this was followed by a decline in the subsequent years, with availability dropping to 95.04 kWh in 2021-22 and slightly rising to 95.72 kWh in 2022-23. Overall, the Average Annual Growth Rate (AAGR) for the period was approximately -0.14%, indicating a slight overall decline in per capita power availability. This suggests that despite periods of improvement, challenges in sustaining long-term growth in power supply remain, reflecting the need for continued efforts to ensure a stable and increasing power availability in the state.

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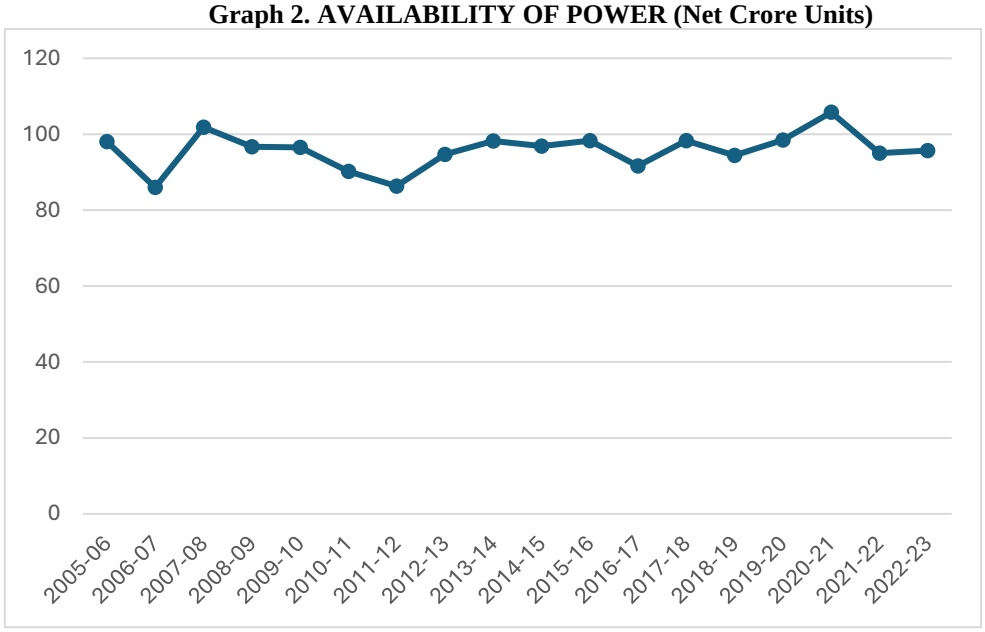
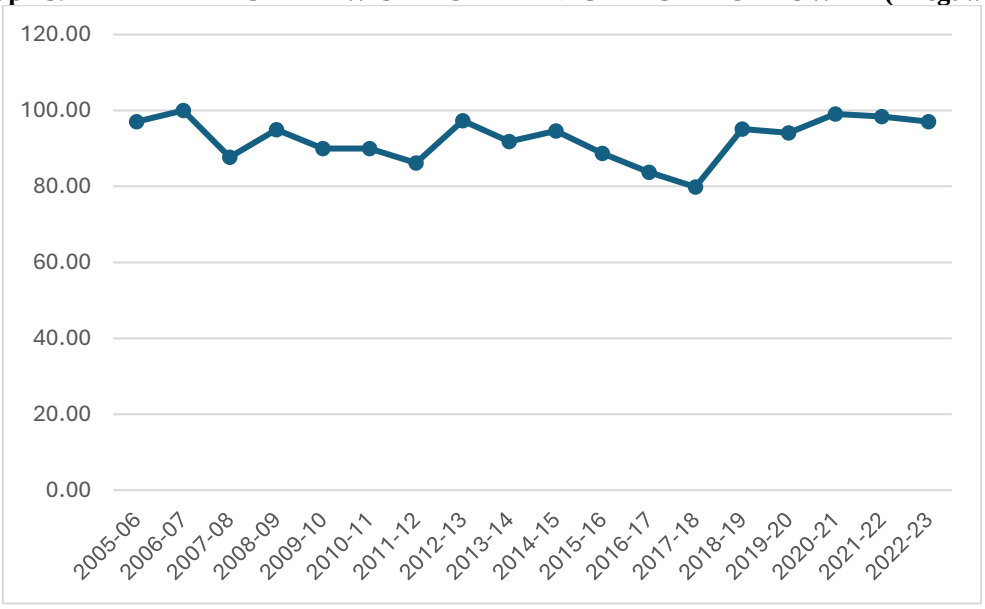
Graph 2. AVAILABILITY OF POWER (Net Crore Units)



Sources: RBI

The data on Karnataka's availability of power in net crore units from 2005-06 to 2022-23 shows a mix of fluctuations, stability, and notable peaks. Initially, from 2005-06 to 2011-12, power availability experienced significant ups and downs, starting at 98.08 crore units, dropping to 85.98 crore units in 2006-07, and then recovering to 101.83 crore units in 2007-08. However, by 2011-12, availability had declined to 86.30 crore units, reflecting instability during this period. From 2012-13 to 2019-20, the state saw a phase of relative stability, with power availability remaining within a narrow range, suggesting more consistent energy production and supply management. The year 2020-21 marked a significant peak, with availability reaching 105.77 crore units, likely influenced by the COVID-19 pandemic's impact on consumption patterns. Following this peak, there was a decline in 2021-22 to 95.04 crore units, with a slight increase to 95.72 crore units in 2022-23, indicating an adjustment to post-pandemic conditions. The overall Average Annual Growth Rate (AAGR) for the period is approximately -0.14%, signifying a slight overall decline in power availability. This trend suggests the need for ongoing efforts to stabilize and increase power supply to meet future demands.

Graph 3.KARNATAKA STATE-WISE INSTALLED CAPACITY OF POWER (Megawatt)



Sources: RBI

The Average Annual Growth Rate (AAGR) of Karnataka's installed power capacity from 2005-06 to 2022-23 reveals a dynamic trend with notable fluctuations. The data indicates periods of significant growth, such as in

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2005-06 and 2018-19, where the growth rates were notably high, reflecting substantial increases in installed capacity. Conversely, there were years with lower growth rates, such as 2016-17 and 2017-18, suggesting slower expansion during these periods. The most recent years demonstrate a trend toward stability, with AAGR values stabilizing between 94% and 98%, signifying a more consistent growth in power capacity. Overall, while the growth rate has varied over time, the general trajectory shows positive development, with recent stability indicating a steady advancement in Karnataka's power infrastructure. This trend highlights both the state's capacity to adapt to varying demands and its ongoing commitment to expanding its power sector.

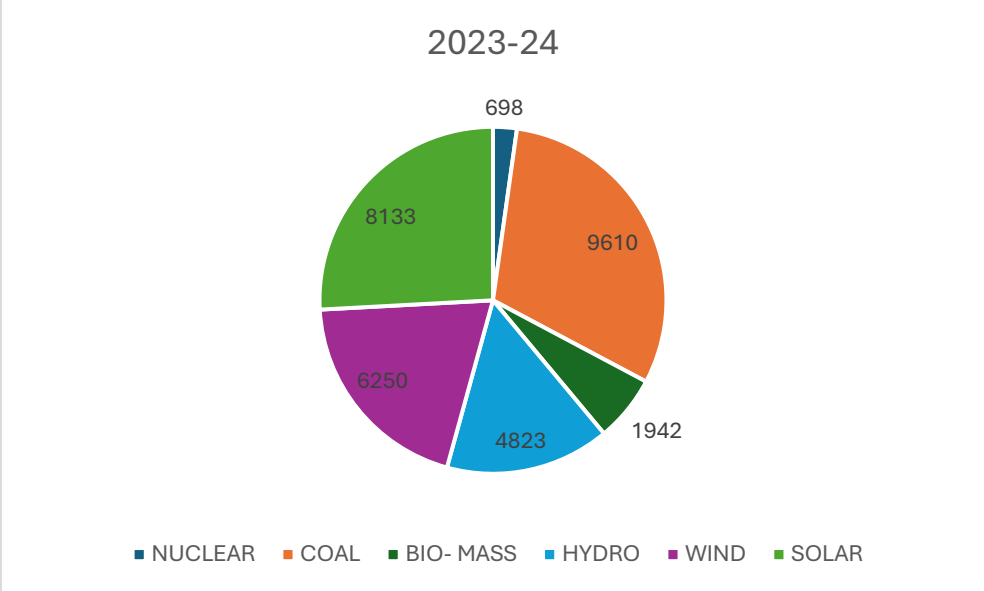
Table 1. Future Energy Demand and Peak Load Forecast for Karnataka (2023-24 to 2031-32)

	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32
Energy Projections (MU)	77876	80922	84132	88232	91852	95486	99758	102973	105970
Year on Year Growth	-	0.0391	0.0397	0.0487	0.041	0.0396	0.0447	0.0322	0.0291
Peak Demand Projections (MW)	15636	16277	16947	17810	18578	19352	20254	20954	21613
Year on Year Growth	-	0.041	0.0412	0.0509	0.0431	0.0417	0.0466	0.0345	0.0314

Sources: Final Draft Report on Resources Adequacy Plan for The state of Karnataka

The projections for energy consumption and peak demand from 2023-24 to 2031-32 indicate a steady rise in both metrics. Energy consumption is expected to increase annually, with growth rates varying between 2.91% and 4.87%, reflecting a gradual rise in demand. Peak demand is also set to grow, with year-on-year increases ranging from 3.14% to 5.09%. This upward trend in peak demand highlights a growing need for additional power generation capacity to meet high-load periods. The variability in growth rates suggests that while both energy consumption and peak demand will consistently rise, the rate of increase will fluctuate, likely influenced by economic and technological factors. These projections underscore the importance of strategic planning and infrastructure development to effectively manage the anticipated growth in energy requirements.

5.Karnataka Energy sources (Magwatt)



Sources: Final Draft Report on Resources Adequacy Plan for The state of Karnataka

In 2023-24, Karnataka's energy generation mix reveals a diverse and evolving strategy. Coal remains the predominant source, providing 9,610 MW, reflecting the state's ongoing reliance on this traditional energy source. However, there is a notable emphasis on renewable energy, with solar power contributing 8,133 MW and wind power 6,250 MW, highlighting significant investments in clean energy technologies. Hydro power adds 4,823 MW, and biomass contributes 1,942 MW, further diversifying the energy portfolio. Nuclear energy, while a smaller component at 698 MW, underscores Karnataka's commitment to integrating low-carbon options. This mix demonstrates a balance between traditional and renewable sources, illustrating the state's efforts to increase sustainability while maintaining robust energy production.

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FINDINGS OF THE STUDY

Karnataka's energy consumption has fluctuated significantly over recent years, with notable variations in per capita and overall power availability. Despite some periods of stability, challenges in maintaining consistent growth in power supply persist.

Coal remains the dominant source of power in Karnataka, though there is a significant emphasis on increasing the share of renewable energy sources, particularly solar and wind. The state also relies on hydro power and biomass, with a minor contribution from nuclear energy.

Energy consumption and peak demand in Karnataka are projected to rise steadily up to 2031-32. Energy consumption is expected to grow between 2.91% and 4.87% annually, while peak demand will increase between 3.14% and 5.09% annually. This trend highlights the need for substantial investments in power generation capacity.

The Average Annual Growth Rate (AAGR) for per capita and overall power availability indicates a slight overall decline. This suggests ongoing challenges in sustaining long-term growth in power supply amidst rising demand. Karnataka has made significant investments in renewable energy, with solar power and wind energy showing substantial contributions to the state's energy mix. However, challenges such as grid integration and variability in renewable energy generation remain.

SUGGESTIONS OF THE STUDY

To accommodate the projected rise in energy consumption and peak demand, Karnataka should invest in expanding and modernizing its power infrastructure. This includes upgrading transmission and distribution networks to reduce losses and improve reliability.

Implementing energy-efficient technologies and practices across all sectors—industrial, residential, and commercial—can help reduce overall energy demand. Programs to promote energy conservation and efficiency should be prioritized.

To support the growing share of renewable energy, Karnataka should focus on improving grid integration technologies and developing energy storage solutions. This will help manage the intermittency of renewable sources and ensure a stable power supply.

Continuing to diversify the energy mix by incorporating more renewable sources and exploring other low-carbon options will contribute to a more sustainable energy future. Investments in emerging technologies, such as smart grids and electric vehicles, should also be encouraged.

Karnataka's energy policies should be revisited and updated to address current challenges and align with future goals. Enhanced policies for renewable energy adoption, energy efficiency, and infrastructure development will support the state’s energy transition.

Special attention should be given to improving energy access and affordability in rural areas. Ensuring equitable distribution of energy resources and infrastructure development will contribute to balanced regional growth.

CONCLUSION

The study provides a comprehensive overview of Karnataka's evolving energy landscape, highlighting key trends and future projections. Over recent years, Karnataka has experienced significant fluctuations in energy consumption patterns, influenced by rapid industrialization, population growth, and urbanization. Despite the dominance of coal as a primary energy source, substantial investments in renewable energy—particularly solar and wind—reflect a strategic shift towards cleaner energy sources.

The analysis of per capita power availability and overall power availability indicates that while there have been periods of improvement, sustaining long-term growth in power supply remains a challenge. The Average Annual Growth Rate (AAGR) for both per capita power availability and overall power availability shows a slight decline, emphasizing the need for ongoing efforts to stabilize and enhance power supply.

The future projections for energy consumption and peak demand up to 2031-32 suggest a steady increase in both metrics, with energy consumption growing at rates between 2.91% and 4.87%, and peak demand rising at rates

from 3.14% to 5.09%. This upward trend underscores the necessity for strategic planning and development of additional power generation capacity to meet future demands.

Karnataka's current energy generation mix demonstrates a balanced approach, with a significant portion of the energy coming from coal, complemented by substantial contributions from renewable sources, hydro power, and biomass. The inclusion of nuclear energy further supports the state's commitment to diversifying its energy portfolio and reducing carbon emissions.

Finally , Karnataka's energy future hinges on effectively managing the transition to renewable energy, improving energy efficiency, and expanding infrastructure to meet growing demands. By adopting balanced energy strategies and addressing the challenges highlighted in the study, Karnataka can support its continued growth and development while striving for a sustainable and reliable energy future.

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