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Digital Transformation through Renewable Energy: A Comparative Analysis of BRICS Nations..

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ABSTRACT

The 21st century demands a shift towards renewable energy, as international bodies, trade groups, and associations urge member states to decrease CO2 emissions through policies promoting sustainable growth. Among these is the BRICS alliance, consisting of Brazil, Russia, India, China, and South Africa - emerging economies that accounted for nearly 30% of global GDP in 2024. A Lancet study on pollution and health highlighted that pollution-induced illnesses caused 16% of worldwide deaths in 2025, totaling 9 million premature fatalities. Air pollution, responsible for 85% of airborne particulate matter, presents the gravest concern. The energy sector, a primary polluter, releases Sulfur oxides (SOx), Nitrogen oxides (NOx), Carbon Monoxide (CO), and Methane (CH4) as key air contaminants. Considering the BRICS nations' global significance, assessing their renewable energy capacity is vital. This research explores the BRICS countries' involvement and accomplishments in the renewable energy field, while also examining how digital transformation influences these endeavors...

Keywords: Renewable Energy, BRICS countries, CO2 emission, Digital transformation.....

INTRODUCTION

Digitalization has become a transformative force in the renewable energy sector, addressing critical challenges and unlocking opportunities for sustainable energy development. By leveraging digital technologies such as smart grids, the Internet of Things (IoT), artificial intelligence (AI), and advanced analytics, the efficiency, reliability, and scalability of renewable energy systems can be significantly improved. This shift is particularly crucial for the BRICS nations (Brazil, Russia, India, China, and South Africa), which are major players in the global energy landscape. These countries collectively account for a substantial share of global energy production and consumption, and the adoption of digitalization in their renewable energy sectors holds tremendous potential to address energy challenges, enhance efficiency, and meet ambitious sustainability goals.

According to *Encyclopaedia Britannica*, renewable energy—also known as alternative or usable energy—is derived from replenishable sources such as solar energy, wind power, hydroelectric power, geothermal energy, tidal power, and biomass. The need for renewable energy has become more urgent than ever in the 21st century. The continuous use of conventional energy sources like coal and fossil fuels for electricity generation has resulted in severe environmental consequences, including climate change.

For example, in 2016, the Earth's average temperature rose by 1.1 degrees Celsius above pre-industrial levels, marking the hottest year in modern history for the third consecutive time. This alarming trend is primarily attributed to the surge in fossil fuel consumption, which

contributes approximately 25% of global greenhouse gas emissions from the electricity sector alone. The burning of fossil fuels leads to environmental degradation, global warming, and adverse health effects.

A recent *Lancet* study highlighted the severe health impacts of fossil fuel combustion and biomass burning. It revealed that air pollution and climate change, caused by these activities, account for 85% of airborne particulate pollution. In 2025, pollution-related diseases were responsible for 9 million deaths worldwide.

Coal and oil remain dominant energy sources globally. In 2025, coal provided nearly 40% of the world's electricity, while oil accounted for 32.9% of global energy consumption. The transport sector alone consumed approximately 63% of the world's oil. These figures underscore the urgent need to transition from conventional energy sources to renewable energy, where digitalization can play a pivotal role in accelerating this shift.

REVIEW OF LITERATURE

Buhari Dogan et al (2025) explains the impact of green technology, research and development on renewable energy. The study found that green technology and research and development positively impact renewable energy innovation. The study suggests that BRICS policymakers should promote green technology, research and development, and digital economy integration to boost renewable energy innovation.

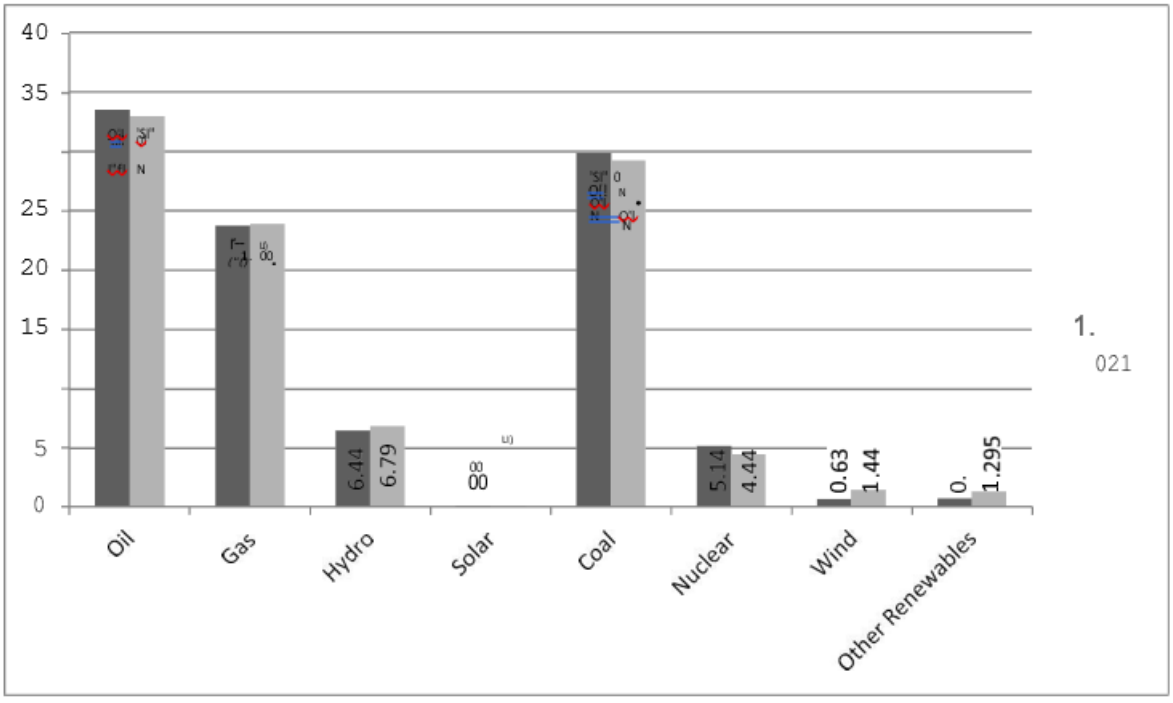
Sheng JIANG et al (2023) explores how governance, ICT, and financial development impact renewable energy generation in BRICS countries from 2000 to 2020. The study highlights the importance of prioritizing a clean environment, improving governance in energy projects, and implementing green ICT strategies to boost renewable energy in BRICS countries.

Jinlong Li (2024) examines how natural resources, digitalization, and load capacity factor (LF) interact in BRICS-T countries (Brazil, Russia, India, China, South Africa, and Turkey) from 1990 to 2019. The study states that digitalization has a positive impact at the median level but is not significant at other levels and policymakers should use GDP and natural resources to improve ecological capacity and address the environmental impacts of globalization and governance.

Han Yuerong et al (2024) examines how digital trade, green technological innovation, renewable energy consumption, globalization, and economic growth affect environmental sustainability in BRICS countries from 2000 to 2019. The study also highlights the Environmental Kuznets Curve and suggests policy measures to ensure environmental sustainability in BRICS economies.

Hind Alofaysan et al (2024) that digitalization, green patterns, and renewable sources positively impact energy efficiency. The study examines how green technology innovation, digitalization, renewable energy use, environmental taxes, GDP, energy prices, and population affect energy efficiency in 22 EU countries. The study suggests investing in digital infrastructure to adopt smart grids, IoT devices, and advanced data analytics for better energy management.

Comparative Primary Energy Consumption in the year 2021 and 2025 (in percentage)



Source: Compiled with the help of World Energy Report, 2016.

From the above bar chart, it is clear that still we majorly depend on oil, coal for our energy needs. But major improvement is achieved in the area of wind and hydro energy.

Review of Literature:

DATA AND METHODOLOGY ADOPTED:

This study employs a descriptive research methodology, utilizing data from the period 2021 to 2025 for BRICS countries. It relies exclusively on secondary data, which has been sourced from reports of international organizations, published journal articles, and books.

OBJECTIVES OF THE STUDY: This study is carried out with the following objectives:

- To analyze the composition of energy production across various sources in BRICS countries.
- To evaluate the energy production mix in BRICS countries during the period 2021 to 2025.
- To assess the contribution of renewable energy sources to total energy production, facilitated by digitalization.

TOOLS USED FOR THE STUDY: Microsoft Excel (2024) is used to do analysis and tabulate the results.

ANALYSIS AND INTERPRETATION:

We have followed the below sequence to carry out our analysis and interpretation:

Brazil

Russia

India

China

South Africa

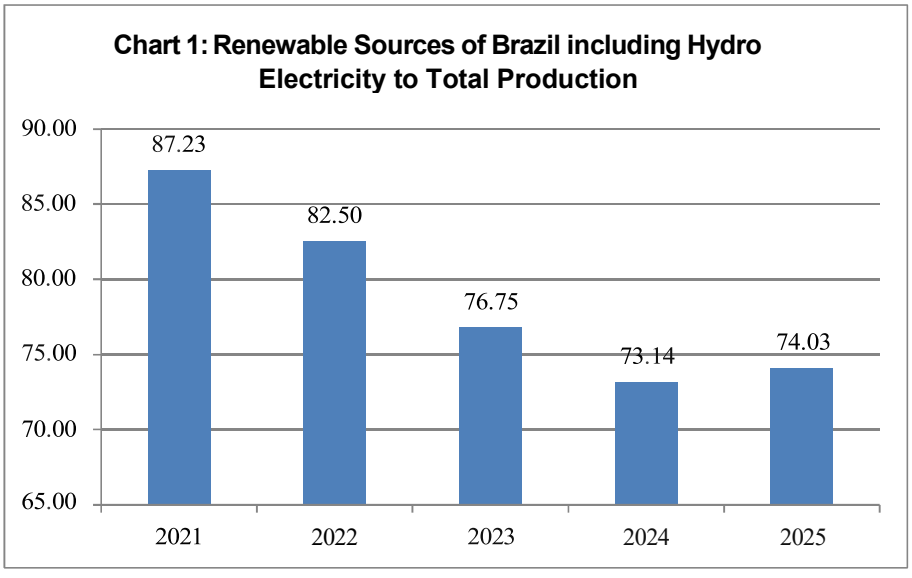
For the purpose of analysis various renewable energy sources is combined. Renewable energy combined includes: Biofuel, Waste (Municipal and Industrial Waste), Hydro power, Geo thermal, Solar PV and Solar thermal, Wind, Tide and Other sources.

Brazil:

Sources	Table 1: Brazil Electricity Generation Mix 2021 – 2025 (*in GWh*)						
	2021	**2022**	**2023**	**2024**	**2025**	**Total**	**Percentage**
Coal	12379	14322	21776	26754	27468	102699	3.63
Oil	14796	19592	26560	35423	29340	125711	4.45
Gas	25095	46760	69002	81075	79490	301422	10.66
Nuclear	15659	16038	15450	15378	14734	77259	2.73
Renewable Sources	**463828**	**455912**	**438308**	**432021**	**430620**	**2220689**	**78.53**
Total	531757	552624	571096	590651	581652	2827780	100.00

Source: International Energy Agency

From the table, it is clear that Brazil is using more renewable sources in its electricity generation mix. Renewable sources account for 78.53% in its electricity mix of cumulative total production mix from 2021-2025. The major contributor to renewable energy in Brazil is hydroelectricity. **The renewable sources show the decreasing trend from 2021 to 2025.**



The above chart depicts the contribution of sources of Renewable Sources of Brazil to its Total Energy Production. We can see the decreasing trend over a period of time. **The reason can be attributable to climate change and decrease in Brazil rainfall**. As Hydro energy primarily depend on the rainfall, which is purely uncertain.

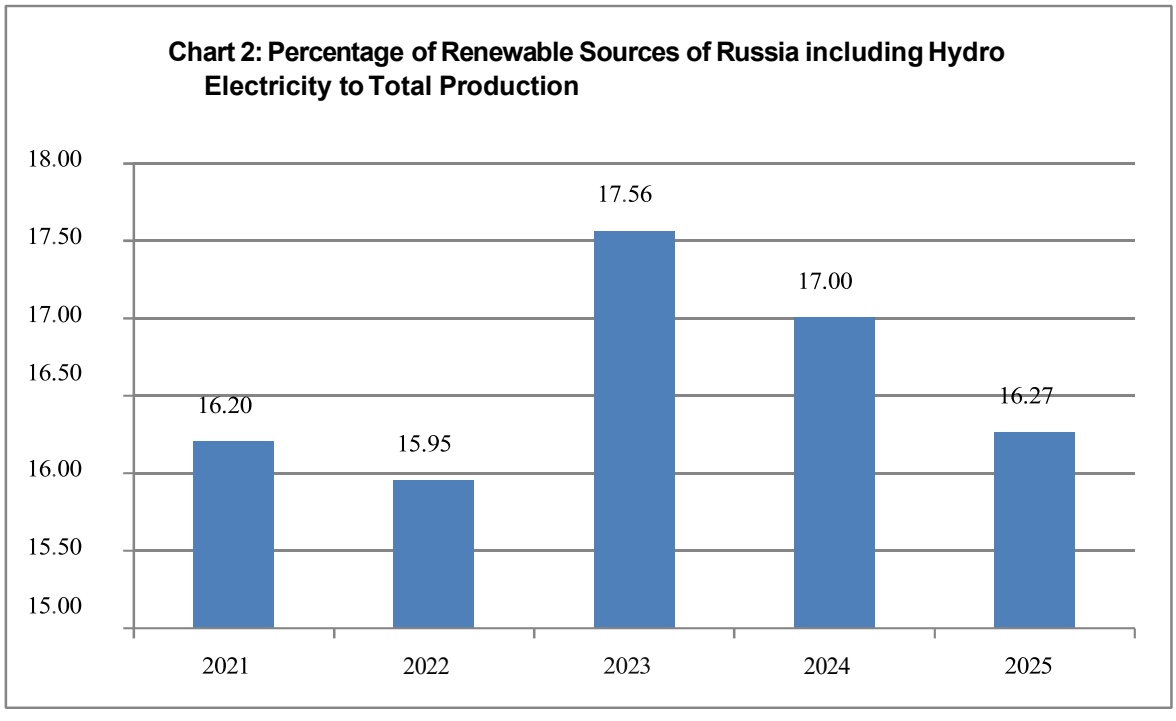
Russia:

Sources	Table 2: Russia Electricity Generation Mix 2021 – 2025 (*in GWh*)						
	2021	**2022**	**2023**	**2024**	**2025**	**Total**	**Percentage**
Coal	164348	168927	161876	158299	158550	812000	15.27
Oil	27362	28062	8706	10703	10102	84935	1.60
Gas	**519202**	**525377**	**529974**	**533493**	**529749**	**2637795**	**49.62**
Nuclear	172941	177534	172508	180757	195470	899210	16.91
Renewable Sources	**170912**	**170834**	**186028**	**180955**	**173673**	**882402**	**16.60**
Total	1054765	1070734	1059092	1064207	1067544	5316342	100.00

Source: International Energy Agency

From the table, it is clear that Russia is primarily using Gas Energy in its electricity generation mix. Renewable sources account for 16.60% of cumulative total production mix from 2021-2025.

Russia is the second largest gas producer in the world after the United States. International Energy Agency 2017 executive report quotes "Almost 90% of the anticipated growth in demand comes from developing economies, led by the People's Republic of China. This indicates Russia can play a bigger role in natural gas requirements of BRICS.



The above chart depicts the contribution of sources of Renewable Sources of Russia to its Total Energy Production. It accounts highest in the year 2023 at 17.56% because of increase in the hydropower and Biofuel. Due to decrease in the hydropower in the year 2024 and 2025 the contribution of renewables sources diminished.

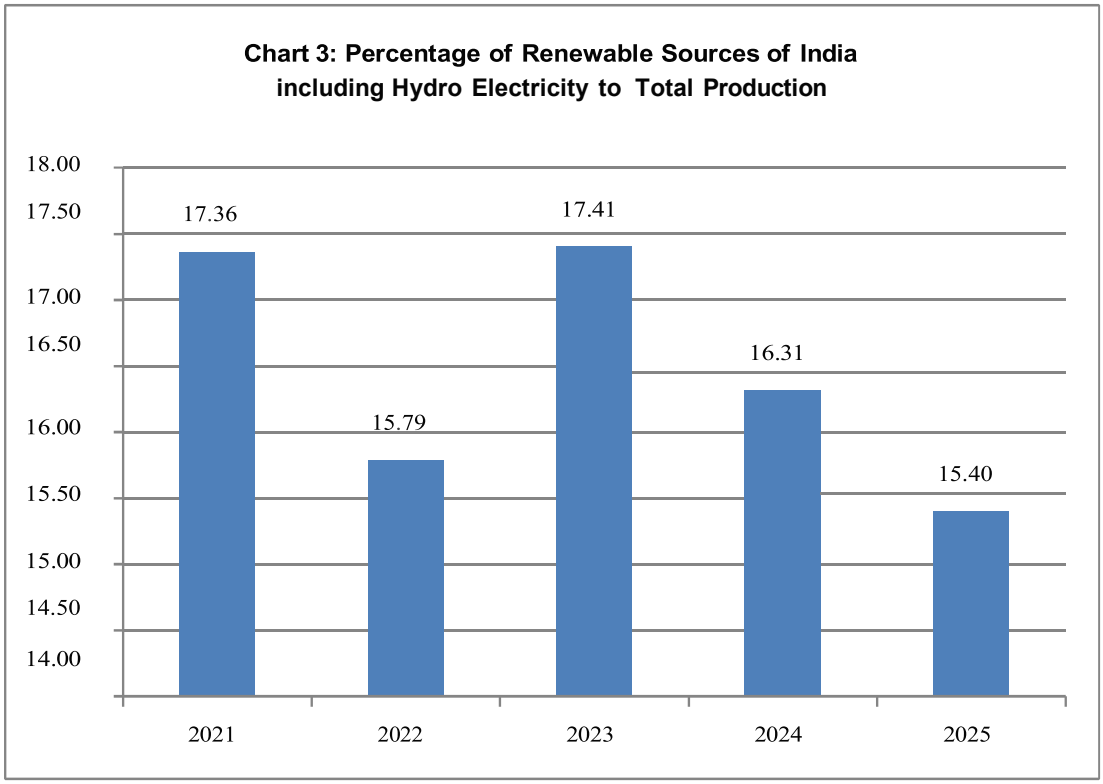
India:

Sources	Table 3: India Electricity Generation Mix 2021 – 2025 (*in GWh*)						
	2021	**2022**	**2023**	**2024**	**2025**	**Total**	**Percentage**
Coal	**717360**	**804508**	**863711**	**963692**	**1041532**	**4390803**	**72.39**
Oil	24125	22886	23299	22865	22951	116126	1.92
Gas	114193	85503	62423	59982	68088	390189	6.43
Nuclear	32287	32866	34228	36102	37413	172896	2.85
Renewable Sources	**186571**	**177286**	**207291**	**211041**	**213020**	**995209**	**16.41**
Total	1074536	1123049	1190952	1293682	1383004	6065223	100.00

Source: International Energy Agency

From the above table, it is clear that India is primarily using Coal Energy in its electricity generation mix. Renewable sources account for 16.41% of cumulative total production mix from 2021-2025. Overall renewable sources contribution shows an increasing trend from 2023-2025.

India is the second largest coal consuming country in 2016. Total coal import shows increasing trend. In the year 2024-15 the total coal import is 217.78 million tonnes when compared to 2021-12 it is 102.85 million tonnes, resulting 111.74%.



The above chart depicts the contribution of sources of Renewable Sources of India to its Total Energy Production. It accounts highest in the year 2023 at 17.41 % because of increase in the hydropower and Biofuel. Due to decline in hydropower in the year 2022 and 2025, the contribution of renewable sources to total production is declined.

China:

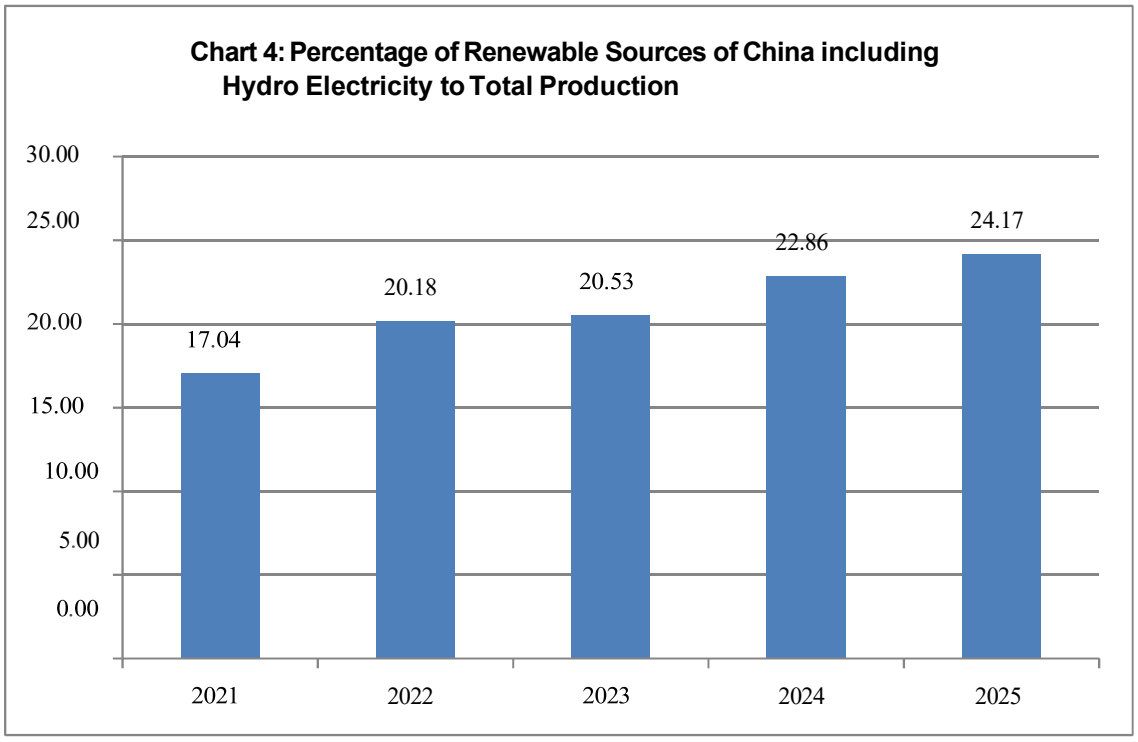
Sources	Table 4: China Electricity Generation Mix 2021 – 2025 (*in GWh)*						
	2021	**2022**	**2023**	**2024**	**2025**	**Total**	**Percent**
Coal	**3738840**	**3798702**	**4121896**	**4145653**	**4133881**	**19938972**	**74.15**
Oil	12245	11766	10171	9748	9866	53796	0.20
Gas	107067	109392	116229	123676	158196	614560	2.29
Nuclear	86350	97394	111613	132538	170789	598684	2.23
Renewable Sources	**810367**	**1015635**	**1126496**	**1307239**	**1425256**	**5684993**	**21.14**
Total	4754869	5032889	5486405	5718854	5897988	26891005	100.00

Source: International Energy Agency

From the above table, it is clear that China is primarily using Coal Energy in its electricity generation mix. Renewable sources account for 21.14% of cumulative total production mix from 2021-2025.

Overall renewable sources contribution shows an increasing trend from 2021-2025.

China is the world's largest coal consuming country in 2016. According to 'The Statistical Portal' – China consumed nearly 1887.6 million metric tonnes oil equivalent.



The above chart depicts the contribution of sources of Renewable Sources of China to its Total Energy Production. It shows increasing trend from 2021 – 2025. This is because China is significantly investing in hydro, solar and wind energy.

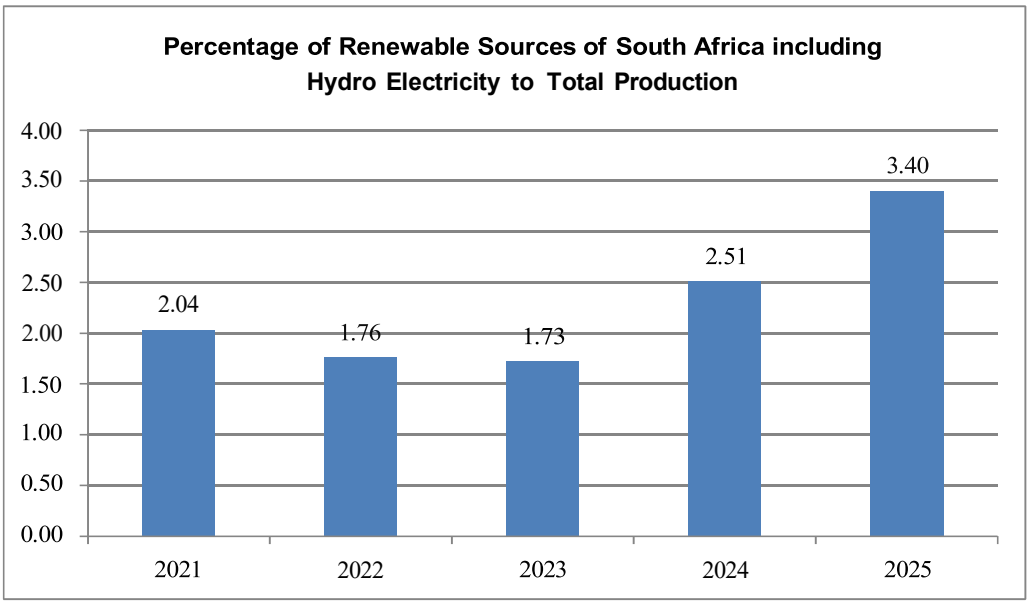
It is worth to mention that in the year 2016 China added 35 GW of new solar energy.

South Africa:

Sources	Table 5: South Africa Electricity Generation Mix 2021 – 2025 (*in GWh*)						
	2021	**2022**	**2023**	**2024**	**2025**	**Total**	**Percent**
Coal	**243493**	**241228**	**237352**	**232262**	**228752**	**1183087**	**92.52**
Oil	197	194	192	189	183	955	0.07
Gas	0	0	0	0	0	0	0.00
Nuclear	13502	11954	14106	13794	12237	65593	5.13
Renewable Sources	**5346**	**4543**	**4423**	**6333**	**8483**	**29128**	**2.28**
Total	262538	257919	256073	252578	249655	1278763	100.00

Source: International Energy Agency

From the above table, it is clear that South Africa is primarily depends Coal Energy in its electricity generation mix. In the year 2025, South Africa Electricity Generation Mix consists 92% from coal energy only.



The above chart depicts the contribution of sources of Renewable Sources of South Africa to its Total Energy Production. It shows increasing trend from 2023 – 2025. Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) which commenced in 2021 made a huge contribution in the renewable energy sector in the area of solar and wind energy.

LIMITATIONS AND AVENUE FOR FURTHER RESEARCH:

The limitations of this study are threefold. Firstly, it relies solely on secondary data, which may limit the depth of analysis and the inclusion of recent developments. Secondly, the study focuses on a specific time frame from 2021 to 2025, potentially overlooking more recent advancements and trends. Finally, the scope is confined to BRICS nations, leaving room for further exploration of digitalization's contributions to renewable energy in other regions and countries. Future research could address these gaps by incorporating primary data, extending the study period, and broadening the geographical focus.

CONCLUSION:

The transition to renewable energy is imperative for mitigating climate change, reducing environmental degradation, and improving public health. Continuous reliance on fossil fuels has led to severe consequences, including global warming and widespread health-related issues. The adoption of renewable energy, especially in emerging economies like the BRICS nations, plays a critical role in addressing these challenges, given their

significant contributions to global energy consumption and greenhouse gas emissions.

The BRICS nations are making commendable progress in their shift toward renewable energy, with Brazil excelling in hydropower usage and China and India investing heavily in solar, wind, and hydroelectric power. South Africa's growing adoption of wind and solar energy, as well as Russia's exploration of digital solutions for renewable projects, further highlight the potential for renewable energy expansion in these regions. However, obstacles such as infrastructure limitations, macroeconomic instability, and continued reliance on coal persist.

Digitalization is proving to be a game-changer in overcoming these challenges. Technologies like smart grids, IoT, AI-driven analytics, and blockchain have improved the efficiency, reliability, and scalability of renewable energy systems in the BRICS nations. In Brazil, predictive analytics and IoT enhance hydropower management, while in India and China, smart grids facilitate the integration of solar and wind energy into their electricity grids. South Africa leverages digital platforms to improve access to renewable energy in underserved areas, and Russia explores blockchain for energy trading and transparency.

The contributions of digitalization are not just technical but also strategic, enabling better policy implementation, decentralized energy distribution, and greater community involvement. To fully harness the potential of renewable energy, BRICS nations must continue investing in digital technologies, fostering policy stability, and addressing infrastructural gaps.

Future research should expand beyond the BRICS nations to include other emerging economies, examining global renewable energy trends, technological advancements, and the role of international collaboration in promoting clean energy initiatives. By embracing digitalization and prioritizing renewable energy, the BRICS nations can lead the way toward a sustainable and resilient energy future....

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