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Research Article

Demand-Supply Gap in Energy Use in BRICS Countries with Special Reference to India - Emerging Challenges and Policies

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Abstract: Brazil, Russia, India, China, and South Africa (BRICS) Energy Research Co-operation Platform (ERCP) is an international program for developing energy-based sustainable development and sharing advanced energy technologies. BRICS is a heterogeneous club of nations having around a quarter of GDP, supplyling energy products to 40 percent of the world's population. The central objectives of the study are (a) the overall production-consumption gap in energy use, (b) details of energy production, consumption; total proved reserves, import, export of energy, growth rate of energy consumption, (c) associations among energy use, demographic, socio-economic and environmental aspects and (d) policy measures undertaken to reduce energy gap along with pathways to the low-carbon environment. The study is based on the secondary data on (a) energy proved reserves, production and consumption for the period 2011-2021, (b) associated demographic, socio-economic, and environment related data obtained from different reports and others. Results have been presented through tabular forms and through figures, and percentages. Among BRICS countries, there are heterogeneous production-consumption gaps for different sources of energy, particularly oil.

***Keywords*:** Climate Change Performance Index (CCPI), Energy Research Co-operation Platform (ERCP), total proved reserves, Reserves to Production Ratio (R/P Ratio), sustainable development, bioenergy

JEL Codes: B17, B27, E23, F02, Q21, Q31

1. Introduction

Brazil, Russia, India, China, and South Africa (BRICS) constitute the members of rapidly developing economies. They are playing very crucial roles in world economic affairs. Energy Research Co-operation Platform (ERCP) of BRICS is an international manifesto for developing energy-based sustainable development. Through ERCP these countries are sharing advanced energy technologies, having cooperation on educational programs, as well as sharing statistical data and plans on the development of national energy systems and information on best practices and regulatory frameworks in the energy sector (Ministry of New and Renewable Energy & Ministry of Power, Govt. of India, 2021).

Global energy trends such as higher energy demand and prices, huge regional differences, structural changes in

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oil and gas industries progressively controlled by national companies, the hope of lasting climate change, as well as demand for energy security underline the necessity for a quick transformation to a low-carbon, reduced fossil, efficient and eco-friendly energy system. The search for energy options involving locally available and renewable resources is one of the critical challenges before governments, scientists and business people globally. Energy may be basically of two types: (a) nonrenewable and (b) renewable.

Nonrenewable energy (fossil fuels): coal, oil, and natural gas has been powering economies for more than 150 years, and currently provide around 80 percent of the world's energy (Environmental and Energy Study Institute (EESI), 2020).

Renewable energy is extracted from natural sources like sunlight, wind and biomass, etc. that are recharged at a higher rate than they are consumed. Bioenergy is one of the various assets available to help to meet our energy demand. It is a form of renewable energy that is derived from recent past living organic materials known as biomass. Clean energy is energy that comes from renewable one, zero-emission sources that do not pollute the atmosphere when used, as well as energy saved by energy efficiency measures. Production and consumption of energy from renewable sources (particularly electricity) have been increasing (TWI, n.d.).

The difference between renewable and nonrenewable energy resources is provided in the following Table (Table 1).

Table 1. Difference between renewable and nonrenewable energy resources

	Renewable resources	Nonrenewable resources
Depletion	Can't be depleted over time	Can be depleted over time
Sources	Sunlight, water, wind, geothermal sources such as hot springs and fumaroles, past living organic materials known as biomass	Fossil fuels such as coal, petroleum
Environmental impact	Low carbon emissions and low carbon footprint	Comparatively higher carbon emissions and higher low carbon footprint
Cost	High upfront cost is high	Comparatively lower upfront cost
Infrastructure requirements	Prohibitively expensive and not easily accessible in most countries	Cost-effective and accessible across most countries
Area requirements	Requires a large land/offshore area	Comparatively lower area requirements

Source: BYJU's (n.d.)

1.1 *Importance of energy for economic development*

Energy is a crucial component of a nation's economic growth and development. It is intensively used in (a) agriculture and its associated sectors such as the manufacturing and delivery of fertilizers, insecticides, and farm implements, (b) transport, and (c) household activities, etc. (GeeksforGeeks, n.d.).

Consumption of commercial energy reports for more than 74 percent of total energy consumption in India. Coal and lignite report for 74 percent of total energy, oil reporting for 10 percent, natural gas for 9 percent and hydro and other new and renewable energy for 7 percent. More than 26 percent of total energy consumption is reported for by non-commercial energy sources such as firewood, cow dung and agricultural scraps. The import dependence of oil and petroleum products, which is predicted to increase quickly, is a key feature of India's energy sector and its relationship to the national economy (GeeksforGeeks, n.d.).

The pattern and trend of sectoral consumption of commercial energy in India is provided in the following Table (Table 2).

Table 2. Pattern and trend of sectoral consumption of commercial energy in India

Sector	1953-1954	1970-1971	1990-1991	2017-2018
Household	10	12	12	24
Agriculture	01	03	08	18
Industries	40	50	45	42
Transport	44	28	22	01
Others	05	07	13	15
Total	100	100	100	100

Source: GeeksforGeeks (n.d.)

1.2 *Energy: A matter of concern*

Powerful socio-economic development needs substantial energy demand and consumption which prominently increase emissions, environmental pollution and influence the health of living bodies. The use of energy resources in industries and transports, etc causes environmental degradation by polluting the environment and climate. Human activities, particularly the burning of fossil fuels, generate the cover of greenhouse gases around the globe. The global warmth is changing the complex web of systems that allow life to thrive on earth. The majority of the world's endangered species (some 25 percent of mammals and 12 percent of birds) may vanish over the next few decades as warmer conditions change the forests, wetlands, and rangelands on which they depend upon, and human development obstructs them from migrating elsewhere. Higher temperatures are likely to expand the extent of some threatening "vector-borne" diseases. In-process environmentally harming activities such as overgrazing, deforestation, and exposed agricultural soils will be more dangerous than previously to climate change. Acid rain is created by the delivery of SOX and NOX from the burning of fossil fuels (GeeksforGeeks, n.d.).

1.3 *Energy conservation, efficiency and security: Their importance*

Coal and other fossil fuels, which took three million or more years to form, are likely to be exhausted in near future. For sustainable development, energy efficiency measures have to be taken. Presently, 85 percent of major energy comes from nonrenewable energy. Energy conservation is attained when the growth of energy consumption is controlled. Energy efficiency is the use of less energy to perform the same activity or to produce the same or enhanced output. Promotion of energy efficiency results in energy conservation (GeeksforGeeks, n.d.).

The energy security for a nation is the reduction of its dependency on the imported energy sources for its economic growth. The International Energy Agency (IEA) was established to confirm secure and affordable energy supplies, and it conducts analysis on current and future risks for oil supply disordering, emerging gas security challenges, and increasing system flexibility and durability of the electricity sector. But energy transitions and the growth of cyber criminality have expanded the scope of what constitutes energy security (IEA, n.d.).

Several challenges have to attain in dealing with energy security: (a) fuel imports, (b) capacity and investment, (c) load factors, (d) renewable, (e) financial condition of distribution utilities, (f) CO_2 emissions, (g) access to modern energy sources, (h) energy intensity and (i) subsidies from governments. Energy security has four aspects: (a) reliability and supply security, (b) economics, (c) access to deliver affordable modern energy and (d) sustainability (Shakti Sustainable Energy Foundation, 2017).

BRICS energy ministers in their joint statement committed to improving efficiency in the utilization of natural resources; strengthening energy efficiency technology to minimize the usage of fossil fuels; strengthening energy security cooperation through joint research on strategic reserves, renewable energy and energy efficiency; and develop investment opportunities for the New Development Bank (NDB), particularly in the areas of renewable energy and energy efficiency (IISD, 2017).

Renewable energy acts a prominent role in supporting energy security through contributing to the protection and continued provision of energy services when a disruption occurs. Origins of disruption to energy services can be natural, technological, and human-caused such as weather events, cyber-attacks, and global market disturbances, etc. (NREL, n.d.).

The environmental benefits from renewable energy are well known. In electricity generation, heat supply, and transport, etc.; renewable energy can increase energy. For those countries where growing dependence on imported gas is a significant energy security issue, renewable energy can provide an alternative and usually indigenous, sources of electric power as well as displacing electricity demand. Renewable energy also, usually, increases the diversity of electricity sources (IEA, n.d.).

1.4 *Objectives and methodology*

The central objective of the paper is to study the overall demand-supply gap in energy use in BRICS countries. The sub-objectives of the paper are to provide details regarding energy and related data for the BRICS countries like (a) energy production, consumption, total proved reserves, Reserves to Production Ratio (R/P Ratio), import and export scenario; (b) energy consumption-production gap; (c) statistics relating to some associated demographic, socio-economic and environmental data, (d) growth rates, world shares of energy consumptions, environmental data and (e) associations among energy, associated demographic, socio-economic and environmental data and (f) policy measures undertaken to reduce the energy gap and pathways to low-carbon environment, etc. The paper is based on secondary data consisting of (1) energy proved reserves, production and consumption for the period 2011-2021, and (2) associated demographic, socio-economic, and environment like (a) population size, (b) Gross Domestic Product (GDP), (c) Human Development Index (HDI), (d) Climate Change Performance Index (CCPI) and (e) carbon dioxide (CO_2) emission obtained from different reports published viz. (a) Statistical Review of World Energy 2022 71st Edition, (b) Statistical Review of World Energy 2021 70th Edition and (c) BRICS Energy Report 2021 and others available through Internet sources. Results have been presented through the tabular forms consisting of figures, percents. Associations among socio-economic-demographic and energy consumption data have been evaluated by Pearsonian product-moment correlation coefficients and their significance have been tested by t test. IBM SPSS software Ver 21 has been utilized for data analyses.

The paper is organized in seven sections as follows: 1. Introduction, 2. Review of literature, 3. General energy scenario in BRICS countries, 4. Scenario of consumption-production gap and policy measures undertaken by BRICS countries to reduce energy gap and pathways to low-carbon environment, 5. Energy imports and exports by BRICS countries, 6. Findings and policy recommendations, 7. Limitations and future research directions.

2. Review of literature

This section contains reviews of papers on energy usage relating to BRICS countries only.

Kurtkoti (2016) mentioned that about 40 percent of the environmental pollution was made by the energy sector. That study examined the necessity of energy consumption and the attempts made by BRICS countries moving towards renewable energy and performed a comparative study of the electricity mix, energy consumption and carbon emissions of BRICS nations. Russia made no efforts, whereas South Africa was getting involved. India started trade dealings with BRICS countries through its 'Make India' program for renewable energy outcomes. Among BRICS, China made the highest dealings for renewable energy. Data sources were secondary data for the period 2000-2014 on energy generation mix, the major methods of power generation present methods of producing Renewable Energy with their emphasis on shifting to Renewable Energy for BRICS countries collected by visiting websites and research articles/papers.

Sahu (2016) pointed out that the BRICS nations were consequential to both the demand and supply of energy markets and energy security in the world including demographic developments with increasing middle-class residents demanding more energy and resources on the basis of secondary data for the year 2014 obtained from Greenpeace BRICS Factsheets 2015. Green Energy Revolution is the remedy to resolve vital socio-economic and environmental effects in their increasing populations. The study highlighted the cooperation among the BRICS countries for the growth of the energy sector, concerning matters relating to climate change and their partnerships in the International Energy

Agency, etc. BRICS is a heterogeneous club with Russia and Brazil are energy exporters while the remaining three have a greater focus on demand and energy security for their continued development.

Shahbaz et al. (2018) evaluated the uneven effect of globalization and economic growth on consumption of energy in BRICS nations by incorporating economic growth and capital as potential determinants in the energy demand function. The factual results reported that a positive disturbance in economic growth increases energy consumption, while a negative shock reduces energy consumption. The data on energy consumption (kg of oil equivalent) and real GDP (constant 2010 US$) and real gross fixed capital formation (constant 2010 US$) were obtained from world development indicators for the period 1970-2015 period. The total population series was utilized to convert energy consumption, real GDP and real gross fixed capital formation into per capita units.

Ndlovu and Inglesi-Lotz (2019) pointed out that with the increasing energy demand, South Africa needs implementing diversified methods of energy generation. There was a heavy dependence on fossil power in the BRICS nations, which promoted for the transition from the current fossil power-dominated energy supply mix to one following international trends but, appreciating its specific geographic position and environmental assets. The data used was Total Primary Energy Supply (TPES), measured in kilotons of oil equivalent (ktoe), of the BRICS and Economic Co-operation and Development (OECD) energy balances, and obtained from the International Energy Agency (IEA) database in 1990-2015. The TPES is energy production plus energy imports, minus energy exports, minus international bunkers, then plus or minus stock changes. It was noticed that the TPES share of non-OECD countries was becoming more prominent, with China, India, and Russia being significant contributors.

Yildirim et al. (2019) investigated the relationship between the consumption of energy and economic growth for Brazil, Russia, China, India, South Africa and Turkey (BRICS-T) nations and came to a conclusion for a bi-directional relationship between them indicating an increase in the Gross Domestic Product (GDP) resulting enhancement in consumption of energy and vice-versa. The data included energy consumption and real output for BRICS-T countries for the period 1990-2014. The variables were transformed into natural logarithm. To analyze those data, Pedroni cointegration test, the second-generation panel cointegration test, Westerlund and Edgerton test and FMOLS test were employed.

Yu et al. (2019) compared the consumption of energy patterns in G7 (an informal grouping of seven of the world's advanced economies: Canada, France, Germany, Italy, Japan, the United Kingdom, the United States) and BRICS nations and pointed out that the research on final consumption of energy, China would have the experience on "low-carbon development" and "energy saving". In the final consumption of energy of the G7 nations, oil and natural gas captured the higher percentage, but for the BRICS nations, the shares of coal, renewable and waste were much higher. Data used for the present study were the World Energy Balances for non-OECD nations between the years 1991-2015 published by the International Energy Agency (IEA), as well as the latest World Energy Balances for OECD nations as primary sources, and uses descriptive statistics to analyze the final energy consumption characteristics of the G7 and BRICS nations.

Khan and Osińska (2021) attempted to forecast the consumption of energy in BRICS nations using the yearly time series data set from the years 1992-2019 from British Petroleum (BP-2019) Statistical Review of World Energy and to check the results obtained from a set of models like Fractional-order Grey Model, Autoregressive Integrated Moving Average (ARIMA) model, etc. The authors concluded that the BRICS countries should monitor energy production and consumption, focusing on the supply-demand gap of energy and its components and facilities provided to local and foreign investors.

The study of Fu et al. (2021) was to examine three key issues: (a) the impact of energy obtained from renewable sources on economic growth, (b) the impact of energy obtained from renewable sources on the emissions of CO_2 by the BRICS countries, and (c) the sensitivity of CO_2 emissions to economic growth and whether or not the Environmental Kuznets Curve (EKC) (used to explain the relationship between economic growth and environmental quality) theory could be proven in the case of BRICS countries. The study applied multiple econometric-based models. The study intended to evaluate the correlation amongst these factors by application of the production function. The findings of the present study recommended that policymakers should encourage the utilization of renewable energy by providing incentives in financial terms.

Ljovkina et al. (2021) pointed out that in spite of the necessity of transitioning to environmentally friendly Renewable Energy System (RES), the implementation and development of renewable energy technologies face some

barriers: (a) socio-cultural, (b) technological, (c) economic, (d) institutional and (e) environmental. To overcome the barriers, the authors utilized the systems approach to gain a deeper understanding of RES interconnection and interdependence. They apply Social, Technological, Economic, Environmental, and Political (STEEP) analysis for classification and qualitative analysis of RES development barriers in Russia. That analytical methodology reported system specifications of the national RES development barriers and predicts the chain reaction of overcoming particular barriers.

Sampene et al. (2021) mentioned about protecting the environment and nurturing long-term growth while minimizing carbon emissions has become a global concern. The BRICS nations are participating in the struggle against climate change through the promotion of Low-Carbon Environment (LCE). Content analysis was utilized to deal with some of the policies, plans, and programs outlined by the governments in the BRICS which might help them implement an LCE. The study, based on data collected from the Climate Action Tracker (CAT) database, rated Brazil, Russia, India, China, and South Africa as "insufficient", "critically insufficient", "compatible", "incompatible" and "highly insufficient" respectively in their commitment to Nationally Determined Contributions (NDC) to the Paris Agreement. It was recommended that the BRICS nations might attain an LCE through expanding low-carbon investments and financing, focusing on taxation that goes beyond energy, investing in low-carbon cities, adapting to a circular economy and low-carbon technologies, expanding electricity markets, and promoting climate-friendly international trade among themselves.

The motivation of the study of Zhang et al. (2021) was to make fresh proof regarding the chain between Economic Policy Uncertainty (EPU) and Renewable Energy Consumption (REC) with the mediating role of Forcing Direct Investment (FDI) and Financial Development (FD) in BRICS countries for the period 1997-2018. The study applied unit root tests following Ng-Perron and Zivot and Andrews for detecting the variable's stationary properties. Study findings predicated that the role of FDI and financial development was critically prominent because technological development and capital investment augment clean energy integration through the application of renewable energy.

Barykina et al. (2022) examined the matters concerning energy availability and production, energy balances and percentages of energy sources in the BRICS nations in the background of sustainable development through the data for the year 2020 obtained from some secondary sources utilizing the methods: comparative analysis, graphical methods of data processing, and synthesis. The study (a) reported the contribution of the BRICS nations to global energy demand and production, (b) forecasted a prominent growth in both energy demand and production and suggested measures to deal with the problems of the energy sector in the BRICS nations.

Mohanty and Sethi (2022) evaluated the role of outward foreign direct investment on the consumption of power quality in BRICS utilizing strongly balanced panel data for BRICS from 1990 to 2019. Utilizing various methodologies like cross-sectional dependence and the Pesaran-Yamagata slope homogeneity for the diagnostic test etc, they suggested that developing nations should provide higher recognition to sustainable development and technological development inspiring higher eco-friendly and environment-friendly technology.

Wang et al. (2022) studied factually the association between fossil power and economic growth in BRICS during the period 1990-2019 using the data obtained from various secondary sources. Fully modified ordinary least squares method was used along with the quadratic function of coal, oil, and gas consumption to evaluate the size-based effect over time. The study indicated that coal and natural gas consumption follows the inverted U-shaped association with the Human Development Index (HDI), while consumption of coal indicated a negative association with HDI. Therefore, the study came to a conclusion: coal and gas power help in development in case of their small size, while over-consumption hinders development. Decreasing fossil power might be replaced with other clean energy resources by utilizing advanced technology such as the gasification process.

2.1 *Discussion of the reviewed literatures and identification of research gap*

Kurtkoti (2016) examined the necessity of energy consumption and the attempts made by BRICS countries moving towards renewable energy, and performed a comparative study of the electricity mix, energy consumption and carbon emissions of BRICS nations.

Sahu (2016) pointed out that the BRICS nations were consequential to both the demand and supply of energy markets and energy security in the world including demographic developments demanding more energy and resources. Green Energy Revolution is the remedy to resolve vital socio-economic and environmental effects in their increasing

populations.

Shahbaz et al. (2018) evaluated the uneven effect of globalization and economic growth on the consumption of energy in BRICS nations by incorporating economic growth and capital as potential determinants in the energy demand function.

Ndlovu and Inglesi-Lotz (2019) pointed out that with the increasing energy demand, South Africa needs implementing diversified methods of energy generation. There was a heavy dependence on fossil power in the BRICS nations, which promoted for the transition from the current fossil power-dominated energy supply mix to one following international trends but, appreciating its specific geographic position and environmental assets.

Yildirim et al. (2019) investigated the relationship between consumption of energy and economic growth for BRICS-T nations and came to a conclusion for a bi-directional relationship between them indicating an increase in the Gross Domestic Product (GDP) resulting enhancement in the consumption of energy and vice-versa.

Yu et al. (2019) compared the consumption of energy patterns in G7 and BRICS nations and pointed out that the research on the final consumption of energy, China would have the experience on "low-carbon development" and "energy saving".

Khan and Osińska (2021) attempted to forecast the consumption of energy in BRICS nations using the yearly time series data set.

The study of Fu et al. (2021) was to examine three key issues: (a) the impact of energy obtained from renewable sources on economic growth, (b) the impact of energy obtained from renewable sources on the emissions of CO_2 by the BRICS countries, and (c) the sensitivity of CO_2 emissions to economic growth and whether or not the EKC theory could be proven in the case of BRICS countries.

Ljovkina et al. (2021) pointed out that in spite of the necessity of transitioning to environmentally friendly Renewable Energy System (RES), the implementation and development of renewable energy technologies face some barriers: (a) socio-cultural, (b) technological, (c) economic, (d) institutional and (e) environmental. To overcome the barriers, the authors utilized the systems approach to gain a deeper understanding of RES interconnection and interdependence.

Sampene et al. (2021) mentioned about protecting the environment and nurturing long-term growth while minimizing carbon emissions has become a global concern. The BRICS nations are participating in the struggle against climate change through the promotion of low-carbon environment.

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Mohanty and Sethi (2022) evaluated the role of outward foreign direct investment on the consumption of power quality in BRICS utilizing strongly balanced panel data.

Wang et al. (2022) studied the association between fossil power and economic growth in BRICS. The study came to a conclusion: coal and gas power helps in development in case of their small size, while over-consumption hinders development. Decreasing fossil power might be replaced with other clean energy resources by utilizing advanced technology such as the gasification process.

2.2 *Identification of research gap*

None of the studies reviewed above, dealt with the demand-supply gap in energy use in BRICS countries along with R/P ratio and growth rates of energy uses. In that sense, the study is an original work.

3. General energy scenario in BRICS countries

In line with their part in the world's energy production and consumption, BRICS countries have a leading character to act in the international energy schedule. Different measures have been taken up by them to further thicken cooperation in the energy sector. BRICS members are heterogeneous in respects of their energy production and consumption. BRICS cooperation in energy is not just about challenging the usual energy system but improving it as well with the purpose of attaining efficiency in the consumption of energy. Consumption of energy is associated with the climate change matters and, BRICS have come up as a specialist in bringing about prospective and efficient clarifications (BRICS Energy Research Platform, Govt. of India, 2021).

The energy sector of BRICS countries, having around a quarter of world's GDP, supplies energy products to 40 per cent of the world's population. The BRICS report for about 43 percent of CO_2 emissions, 42 percent of energy products from renewable energy resources and 37 percent of energy consumption of the world. In various ways, energy development trends in the BRICS nations will carry on with acting a vital role in the energy sector in the world (Barykina et al., 2022).

Energy scenarios of the BRICS are as follows.

3.1 *Brazil*

Total energy consumption was 308 Mtoe in 2021. Brazil's oil production grew at a rate of 5.5 percent annually during 2013-2020, and decreased in 2021 (-1 percent) to 152 Mt. Brazil is a net exporter of crude oil (net exports of 57 Mt in 2021): crude oil exports have been enhancing by about 20 percent annually during 2013-2020, meeting 70 Mt in 2020. They reduced by 2.5 percent in 2021. Oil product consumption reduced during 2014-2020 (-4 percent annually) and overcame in 2021 to 104 Mt (+7.5 percent). The transport sector is the vital oil consumer (59 percent), followed by industry (11 percent), the residential-tertiary sector (13 percent), non-energy uses (11 percent), power plants (4 percent), and the hydrocarbon industry (2 percent). Natural gas consumption overcame rapidly in 2021 to 42 billion cubic metres (bcm) (+23 percent). Coal consumption overcame in 2021 (+24 percent) touching 29 Mt. Consumption of electricity overcame in 2021 by 8.6 percent to 579 TWh. (Enerdata, 2021a).

3.2 *Russia*

Total energy consumption enhanced during 2015-2019 (2.6 percent annually) and then reduced by 4 percent in 2020. In 2020, gas constituted the maximum portion of consumption (55 percent), followed by oil (19 percent), coal (15 percent), nuclear (8 percent), hydro (2 percent) and biomass (1 percent). Oil production enhanced by 1.4 percent annually during 2014-2019, touching 561 Mt in 2019, decreased by about 9 percent in 2020 to 512 Mt. Russia was the globally second largest crude oil producer in 2020, after the USA. Consumption of oil remained constant during 2012-2019 at about 150 Mtoe and then decreased by about 4 percent in 2020 to 144 Mt. Transport was the highest oil-consuming sector with 40 percent of total oil products followed by industry (31 percent), hydrocarbon sector (14 percent) and residential-services-agriculture sector (12 percent). Consumption of gas enhanced by 12.8 percent annually during 2017-2019 and then deduced by about 3.3 percent to 493 bcm in 2020. Gas is mostly consumed in the electricity sector (37 percent). Industry reports 25 percent and residential-services sector 18 percent. Consumption of coal and lignite enhanced by 2.8 percent annually during 2014-2019 and then reduced by 10.6 percent in 2020 to 210 Mt. Consumption of electricity enhanced during 2010-2019 (0.9 percent annually) and then reduced by 2.4 percent to 909 TWh in 2020. Industry is the major electricity user with 36 percent, followed by residential sector with 18 percent and services with 16 percent (Enerdata, 2021d).

3.3 *China*

Consumption of total energy per capita enhanced touching 2.6 toe/cap in 2021 (nearly 4 times that for India). Consumption of electricity per capita was 5,450 kWh in 2021. Oil product was 208 Mt in 2021. The oil products consumption was 689 Mt in 2021. In 2021, consumption of natural gas was 358 bcm. Industry demands for 41 percent of natural gas, followed by the residential and services sector (22 percent), the power sector (17 percent) and transport (10

percent). Consumption of coal and lignite in 2021 was 4.1 Gt. The power sector is the greatest user of coal and lignite, with 66 per cent, followed by industry (25 percent). Consumption of electricity in 2021 was 7,714 TWh. China plans to get 20 per cent of its total energy consumption from non-fossil fuels in 2025 (16 percent in 2020). China imported 540 million tonnes of crude oil in 2020, refined oil 28 million tonnes, natural gas 140 billion cubic metres. Coal imports were 300 million tones, coal exports were about 3 million tonnes (Enerdata, 2021b).

3.4 *South Africa*

In 2021, (a) total per capita energy consumption was 2.3 toe, (b) per capita electricity consumption was 3,284 kWh in 2021 and (c) total oil production was 4.9 Mt. In 2021, the country imported 13 Mt of crude oil and 13 Mt of oil products (net imports). Transport reports for 65 percent of oil consumption, followed by industry (18 percent), residential-services-agriculture (10 percent) and power plants (7 percent). Consumption of gas consumption was 4.8 bcm in 2021. Consumption of coal in 2021 was 188 Mt. Consumption of electricity was 197 TWh in 2021. Industry is the major electricity consumer (52 percent), followed by the residential sector (20 percent) and the services sector (15 percent) (Enerdata, 2021e).

3.5 *India*

Total energy consumption touched 927 Mtoe in 2021. Coal is the country's top energy resource (44 percent) in 2021, followed by oil (24 percent) and biomass (22 percent), natural gas (6 percent) and electricity 4 percent. Production of oil enhanced to 43 Mt in 2021. India is the third highest importer of crude oil in the world, with imports of 210 Mt in 2021. India is a net oil product exporter (24 Mt in 2021). Of the total consumption of oil for 2021, transport used 41 percent, industry (32 percent), residential-service-agriculture sector (21 percent), power plants (1 percent) and hydrocarbon industry (5 percent). Gas consumption was 65 bcm in 2021, industry is the major consumer of gas with 48 per cent, followed by production of electricity (25 percent), transport (5 percent) and the residential and services sector (7 percent). Coal and lignite consumption reported 1.02 Gt in 2021. In 2021, power generation and industry were the major consumers of coal and lignite, with 74 percent and 21 percent respectively. In 2021, consumption of electricity enhanced by about 5 percent to 1355 TWh (Enerdata, 2021c).

India has an important role in the world energy economy. In the last decade, India's energy consumption has increased with a Compound Annual Growth Rate (CAGR) of 4.11 percent. The total electricity production increased annually with a CAGR of 5.63 percent during the last decade. Out of the total electricity consumption in 2019-2020, the industry sector consumed the highest share (42.7 percent), followed by domestic (24.0 percent), agriculture (17.7 percent), and commercial sectors (8.0 percent). India is the second-largest producer of coal in the world, next to China. The portion of coal in both the energy mix and the power mix in India is high, and in 2020 fossil fuel provided about 74 percent of the total electricity production. India is one of the biggest importers of crude oil, but it is also one of the biggest exporters of refined oil (BRICS Energy Research Platform, Govt. of India, 2021).

4. Scenario of consumption-production gap and policy measures undertaken by BRICS countries to reduce energy gap and pathways towards low-carbon environment

Primary energy is the total energy demand of a country. It covers consumption of the energy sector itself, losses during the transformation and distribution of energy, and the final consumption by end users.

Some factors such as greenhouse gas emissions, GDP, population size and labor growth have a positive association with energy consumption (Zaharia et al., 2019).

More developed nations have higher HDIs, therefore usually countries with greater energy use possess greater levels of human development (Energy Education, n.d.).

It is obvious that industrialization and energy consumption are highly positively associated. Gas flaring is the burning of natural gas linked with the extraction of oil. The major consumed primary energy fuel in the world is oil.

Population size, GDP, HDI and CCPI for BRICS nations are provided in the following Table (Table 3).

Table 3. Population size, GDP, HDI and CCPI for BRICS nations

Nation	Population[a] (Crores) 2022 estimate	GDP[b] (Billions $)	HDI[a] 2019	CCPI[c] 2022
Brazil	21.531	1,810.612	0.765	54.86
Russia	14.471	1,703.527	0.824	34.73
India	141.717	3,250.078	0.645	69.20
China	142.589	18,463.130	0.761	52.20
South Africa	59.894	435.212	0.709	51.13

Sources: [a](World Population Review, n.d.)
[b](Geoworld, 2022)
[c](New Climate Institute, n.d.)

HDI and CCPI are significantly negatively associated (correlation coefficient is -0.904, P-Value = 0.035).

India is the third largest energy-consuming nation in the world (PSU CONNECT, 2022).

Statistics of primary energy consumption (in Exajoules) in BRICS nations is provided in the following Table (Table 4).

Table 4. Primary energy consumption (in Exajoules) in BRICS nations

Nation	2011	2015	2019	2020	2021	Growth rate per annum (%)		World share (%) 2021
						2021	2011-2021	
Brazil	11.80	12.40	12.56	12.00	12.57	5.0	0.6	2.1
Russia	29.09	28.37	30.02	28.88	31.30	8.7	0.7	5.3
India	23.94	28.91	31.15	32.19	35.43	10.4	4.0	6.0
China	112.80	127.02	143.92	147.58	157.65	7.1	3.4	26.5
South Africa	5.20	5.10	5.36	4.95	4.98	0.8	-0.4	0.8

Source: bp (2022)

Primary energy consumption in South Africa has decreased over the period 2011-2021. Among BRICS nations, the growth rate of primary energy consumption in 2021 is highest in India, followed by Russia and China.

Statistics of primary energy consumption by fuel (in Exajoules) in BRICS nations for 2021 is provided in the following Table (Table 5).

Fossil energy consists of oil, natural gas and coal is the major source of energy.

For China, India and South Africa, coal is having the highest share, followed by oil. In the case of South Africa, coal occupies about 71 percent of primary energy consumption. In case of Brazil, oil is having the highest share, followed by hydroelectricity. In case of Russia, natural gas is having the highest share, followed by oil.

Statistics of primary energy consumption per capita (in Gigajoules) in BRICS nations is provided in the following Table (Table 6).

Table 5. Primary energy consumption by fuel (in Exajoules) in BRICS nations for 2021 (percents given in brackets)

Nation	Oil	Natural gas	Coal	Nuclear energy	Hydro-electricity	Renewables	Total
Brazil	4.46 (35.5)	1.46 (11.6)	0.71 (5.6)	0.13 (1.1)	3.42 (27.2)	2.39 (19.0)	12.57 (100)
Russia	6.71 (21.4)	17.09 (54.6)	3.41 (10.9)	2.01 (6.4)	2.02 (6.5)	0.06 (0.2)	31.30 (100)
India	9.41 (26.6)	2.24 (6.3)	20.09 (56.7)	0.40 (1.1)	1.51 (4.3)	1.79 (5.0)	35.43 (100)
China	30.60 (19.4)	13.63 (8.6)	86.17 (54.7)	3.68 (2.3)	12.25 (7.8)	11.32 (7.2)	157.65 (100)
South Africa	1.04 (20.9)	0.14 (2.8)	3.53 (70.9)	0.09 (1.9)	0.01 (0.2)	0.16 (3.3)	4.98 (100)

Source: bp (2022)
Per cents are calculated by the authors

Table 6. Primary energy consumption per capita (in Gigajoules) in BRICS nations

Nation	2011	2015	2019	2020	2021	Growth rate per annum (%)	
						2021	2011-21
Brazil	59.7	60.6	59.4	56.4	58.7	4.3	-0.2
Russia	202.4	195.6	205.8	197.9	214.5	8.7	0.6
India	19.1	22.0	25.0	23.3	25.4	9.3	2.9
China	81.9	90.2	100.3	102.5	109.1	6.8	2.9
South Africa	99.8	91.8	91.4	83.4	82.8	-0.4	-1.9

Source: bp (2022)

Primary energy consumption per capita in South Africa and Brazil has decreased over the period 2011-2021. Among BRICS nations, the growth rate of primary energy consumption per capita in 2021 is highest in India, followed by Russia and China.

GDP (mentioned in Table 3) and primary energy consumption (mentioned in Table 4) are significantly highly positively associated (correlation coefficient is 0.993, P-Value < 0.001) implying that an increase of income (GDP) leads to an increase in primary energy consumption and vice-versa.

HDI (mentioned in Table 3) and primary energy consumption per capita (mentioned in Table 6) are significantly positively associated (correlation coefficient is 0.847, P-Value = 0.069) implying that an increase of HDI leads to an increase in primary energy consumption and vice-versa.

CCPI (mentioned in Table 3) and primary energy consumption per capita (mentioned in Table 6) are significantly highly negatively associated (correlation coefficient is -0.950, P-Value = 0.013) implying that an increase of CCPI leads to a reduction in primary energy consumption per capita and vice-versa.

Proved reserves mean the amount of natural resources that a nation expects to extract from a natural formation. Proven reserves are calculated using geological and engineering data collected through seismic testing and exploratory drilling. The Reserves-to-Production Ratio (R/P Ratio) is an estimate of the number of years that the site of a natural resource will continue to be productive based on current production and consumption rates. Total proved reserves at the end 2020 of oil, natural gas and coal for the BRICS nations are provided in the following Table (Table 7).

South Africa is weak in the context of total proved reserves.

Statistics of CO_2 emissions from energy, natural gas flaring, CO_2 equivalent emissions from energy, process emissions, flaring in BRICS nations in 2021 are provided in the following Table (Table 8).

Table 7. Total proved reserves at end 2020 of oil, natural gas and coal for BRICS nations

Nation	Oil			Natural gas			Coal		
	Thousand million barrels	World share (%)	R/P Ratio	Trillion cubic metres	World share (%)	R/P Ratio	Million tonnes	World share (%)	R/P Ratio
Brazil	11.9	0.7	10.8	0.3	0.2	14.6	6,596	0.6	*
Russia	107.8	6.2	27.6	37.4	19.9	58.6	162,166	15.1	407
India	4.5	0.3	16.1	1.3	0.7	55.6	111,052	10.3	147
China	26.0	1.5	18.2	8.4	4.5	43.3	143,197	13.3	37
South Africa	NA	NA	NA	NA	NA	NA	9,893	0.9	40

Source: bp (2021)
*More than 500 years
NA: Not Available

Table 8. Statistics of CO_2 emissions from energy, natural gas flaring, CO_2 equivalent emissions from energy, process emissions, flaring in BRICS nations in 2021

Nation	CO_2 emissions from energy			Natural gas flaring			CO_2 equivalent emissions from energy, process emissions, flaring		
	2021	Growth rate (%) 2020-2021	World share (%) 2021	2021	Growth rate (%) 2020-2021	World share (%) 2021	2021	Growth rate (%) 2020-2021	World share (%) 2021
Brazil	436.6	12.1	1.3	1.1	-4.7	0.7	495.8	10.8	1.3
Russia	1,581.3	8.9	4.7	26.4	5.6	17.3	2,172.1	8.3	5.6
India	2,552.8	12.2	7.5	1.9	-7.8	1.2	2,797.2	12.5	7.2
China	10,523.0	5.8	31.1	2.7	-6.5	1.8	12,039.8	5.3	30.9
South Africa	438.9	0.7	1.3	NA	NA	NA	472.9	0.4	1.2

Source: bp (2022)
NA: Not Available

Among the BRICS nations, China has the maximum share of CO_2 emissions from energy and CO_2 equivalent emissions from energy, process emissions, flaring; Russia has the maximum share of natural gas flaring.

GDP (mentioned in Table 3) is significantly highly positively associated with CO_2 emissions from energy, CO_2 equivalent emissions from energy, process emissions and flaring: in case of CO_2 emissions from energy (correlation coefficient is 0.993, P-Value < 0.001) and in case of CO_2 equivalent emissions from energy, process emissions and flaring (correlation coefficient is 0.991, P-Value < 0.001). Primary energy consumption (mentioned in Table 4) is significantly highly positively associated with CO_2 emissions from energy, CO_2 equivalent emissions from energy, process emissions, flaring: in case of CO_2 emissions from energy (correlation coefficient is 0.997, P-Value < 0.001) and in case of CO_2 equivalent emissions from energy, process emissions and flaring (correlation coefficient is 0.999, P-Value < 0.001).

Primary energy consumption per capita (mentioned in Table 6) and natural gas flaring are significantly highly positively associated (correlation coefficient is 0.904, P-Value = 0.035).

CO_2 emissions from energy and CO_2 equivalent emissions from energy, process emissions, flaring are significantly highly positively associated (correlation coefficient is 0.999, P-Value < 0.001).

Statistics of oil: production and consumption (thousand barrels) daily in BRICS nations in 2021 are provided in the following Table (Table 9).

Table 9. Statistics of oil: Production and consumption (thousand barrels) daily in BRICS nations in 2021

Nation	Production			Consumption			Gap = Production – Consumption
	2021	Growth rate (%) 2020-2021	World share (%) 2021	2021	Growth rate (%) 2020-2021	World share (%) 2021	
Brazil	2,987	-1.4	3.3	2,252	5.5	2.4	735
Russia	10,944	2.6	12.2	3,407	6.1	3.6	7,537
India	748	-3.2	0.8	4,878	3.8	5.2	-4,130
China	3,994	2.4	4.4	15,442	7.2	16.4	-11,448
South Africa	NA	NA	NA	502	7.9	0.5	-502

Source: bp (2022)
NA: Not Available

Brazil and Russia have excess oil production compared to their respective consumptions, but India, China and South Africa have insufficient oil production compared to their respective consumptions.

Oil consumption per day is significantly highly positively associated with GDP (mentioned in Table 3), primary energy consumption (mentioned in Table 4), CO_2 emissions from energy, CO_2 equivalent emissions from energy, process emissions, flaring (mentioned in Table 8): in case of GDP (correlation coefficient is 0.988, P-Value = 0.002), in case of primary energy consumption (correlation coefficient is 0.995, P-Value < 0.001), in case of CO_2 emissions from energy (correlation coefficient is 0.993, P-Value < 0.001) and in case of CO_2 equivalent emissions from energy, process emissions, flaring (correlation coefficient is 0.993, P-Value < 0.001).

Statistics of natural gas: production and consumption (billion cubic meters) in BRICS nations in 2021 are provided in the following Table (Table 10).

Table 10. Statistics of natural gas: Production and consumption (billion cubic metres) in BRICS nations in 2021

Nation	Production			Consumption			Gap = Production – Consumption
	2021	Growth rate (%) 2020-2021	World share (%) 2021	2021	Growth rate (%) 2020-2021	World share (%) 2021	
Brazil	24.3	0.7	0.6	40.4	29.1	1.0	-16.1
Russia	701.7	10.4	17.4	474.6	12.4	11.8	227.1
India	28.5	20.4	0.7	62.2	3.1	1.5	-33.7
China	209.2	8.1	5.2	378.7	12.8	9.4	-169.5
South Africa	NA	NA	NA	3.9	-2.7	0.1	-3.9

Source: bp (2022)
NA: Not Available

Russia has excess natural gas production compared to their respective consumptions, but Brazil, India, China and South Africa have insufficient natural gas production.

The consumption of natural gas and primary energy consumption per capita (mentioned in Table 6) are significantly positively associated (correlation coefficient is 0.0.848, P-Value = 0.069).

Statistics of coal: production and consumption (exajoules) in BRICS nations in 2021 are provided in the following Table (Table 11).

Table 11. Statistics of coal: Production and consumption (Exajoules) in BRICS nations in 2021

Nation	Production			Consumption			Gap = Production – Consumption
	2021	Growth rate (%) 2020-2021	World share (%) 2021	2021	Growth rate (%) 2020-2021	World share (%) 2021	
Brazil	0.12	23.4	0.1	0.71	21.6	0.4	-0.59
Russia	9.14	8.8	5.5	3.41	4.0	2.1	5.73
India	13.47	6.9	8.0	20.09	15.8	0.1	-6.62
China	85.15	6.0	50.8	86.17	4.9	53.8	-1.02
South Africa	5.55	-4.3	3.3	3.53	-0.5	2.2	2.02

Source: bp (2022)

Russia and South Africa have excess coal productions compared to their respective consumptions, but Brazil, India have insufficient coal productions compared to their respective consumptions. China's coal production is slightly less than its coal consumption. In India, there is an energy shortage of about 4.3 percent and peak of 5.4 percent. Various initiatives have been made to manage the demand supply gap in energy by Government of India in the past. Growing capacity addition and renewable energy has helped in large way. It is estimated by Ministry of Power, Government of India that about 23 percent of energy can be saved by adopting energy efficiency among all energy users (Jha et al., 2014).

Coal consumption is significantly positively associated with GDP (mentioned in Table 3) (correlation coefficient is 0.991, P-Value < 0.001), primary energy consumption (correlation coefficient is 0.986, P-Value = 0.002), CO_2 emissions from energy (mentioned in Table 8) (correlation coefficient is 0.995, P-Value < 0.001), CO_2 equivalent emissions from energy, process emissions, flaring (correlation coefficient is 0.990, P-Value < 0.001) and oil consumption (correlation coefficient is 0.983, P-Value = 0.003).

Statistics of consumption of nuclear energy, hydroelectricity and renewable energy (exajoules: input-equivalent) in BRICS nations in 2021 are provided in the following Table (Table 12). "Input-equivalent" energy is the magnitude of fuel that would be necessary by the thermal power stations to produce the mentioned electricity output.

Table 12. Statistics of consumption of nuclear energy, hydroelectricity, renewable energy (Exajoules: Input-equivalent) in BRICS nations in 2021

Nation	Nuclear energy			Hydroelectricity			Renewable energy		
	2021	Growth rate (%) 2020-2021	World share (%) 2021	2021	Growth rate (%) 2020-2021	World share (%) 2021	2021	Growth rate (%) 2020-2021	World share (%) 2021
Brazil	0.13	4.5	0.5	3.42	-8.6	8.5	2.39	9.5	6.0
Russia	2.01	2.9	7.9	2.02	0.9	5.0	0.06	53.9	0.2
India	0.40	-1.6	1.6	1.51	-2.2	3.8	1.79	13.2	4.5
China	3.68	11.2	14.6	12.25	-1.7	30.4	11.32	33.1	28.4
South Africa	0.09	-25.3	0.4	0.01	101.4	*	0.16	4.9	0.4

Source: bp (2022)
*Less than 0.05 per cent

Among BRICS countries, China is leading in the consumptions of nuclear energy, hydroelectricity and renewable energy and South Africa is lagging behind all its BRICS co-members.

Nuclear energy consumption is significantly positively associated with GDP (mentioned in Table 3) (correlation coefficient is 0.861, coefficient of determination is 0.741, P-Value = 0.061), primary energy consumption (mentioned in Table 4) (correlation coefficient is 0.906, P-Value = 0.034), CO_2 emissions from energy (mentioned in Table 8) (correlation coefficient is 0.882, P-Value = 0.048), CO_2 equivalent emissions from energy, process emissions, flaring (correlation coefficient is 0.900, P-Value = 0.038) and oil consumption (correlation coefficient is 0.882, P-Value = 0.048), natural gas consumption (correlation coefficient is 0.855, P-Value = 0.065), coal consumption (correlation coefficient is 0.831, P-Value = 0.080).

Hydroelectricity consumption is significantly positively associated with GDP (correlation coefficient is 0.973, P-Value = 0.005), primary energy consumption (correlation coefficient is 0.959, P-Value = 0.009), CO_2 emissions from energy (correlation coefficient is 0.945, P-Value = 0.016), CO_2 equivalent emissions from energy, process emissions, flaring (correlation coefficient is 0.946, P-Value = 0.015) and oil consumption (correlation coefficient is 0.956, P-Value = 0.011), coal consumption (correlation coefficient is 0.934, P-Value = 0.020), nuclear energy consumption (correlation coefficient is 0.853, P-Value = 0.066), renewable energy consumption (correlation coefficient is 0.982, P-Value = 0.003).

Renewable energy consumption is significantly positively associated with GDP (correlation coefficient is 0.985, P-Value = 0.002), primary energy consumption (correlation coefficient is 0.959, P-Value = 0.009), CO_2 emissions from energy (correlation coefficient is 0.958, P-Value = 0.009), CO_2 equivalent emissions from energy, process emissions, flaring (correlation coefficient is 0.953, P-Value = 0.012) and oil consumption (correlation coefficient is 0.960, P-Value = 0.009), coal consumption (correlation coefficient is 0.966, P-Value = 0.008), hydroelectricity consumption (correlation coefficient is 0.982, P-Value = 0.003.

Statistics of electricity (terawatt-hours) generation, generation by fuel and consumption in BRICS nations in 2021 are provided in the following Table (Table 13).

Table 13. Statistics of electricity (terawatt-hours) generation*, generation by fuel and consumption in BRICS nations in 2021 (percents given in brackets)

Nation	Electricity generation			Electricity generation by fuel						Electricity consumption+
	2021	Growth rate (%) 2020-2021	World share (%) 2021	Oil	Natural gas	Coal	Nuclear energy	Hydro	Renewables and others	
Brazil	654.4 (100)	5.6	2.3	21.9 (3.3)	86.9 (13.3)	24.1 (3.7)	14.7 (2.3)	362.8 (55.4)	144.0 (22.0)	597.1 (2019 est)
Russia	1,157.1 (100)	6.9	4.1	8.5 (0.7)	496.8 (43.1)	204.7 (17.7)	222.4 (19.2)	214.5 (18.4)	10.1 (0.9)	965.2 (2019 est)
India	1,714.8 (100)	10.0	6.0	2.3 (0.2)	64.2 (3.7)	1,271.1 (74.1)	43.9 (2.6)	160.3 (9.3)	173.0 (10.1)	1,383.4 (2020 est)
China	8,534.3 (100)	10.0	30.0	12.2 (0.1)	272.6 (3.2)	5,339.1 (62.6)	407.5 (4.8)	1,300.0 (15.2)	1,202.7 (14.1)	8,312.8 (2021)
South Africa	244.3 (100)	2.3	0.9	1.6 (0.7)	0.0 (0.0)	209.6 (85.7)	10.4 (4.3)	1.4 (0.6)	21.3 (8.7)	210.3 (2019 est)

Source: bp (2022)
+List of cuntries by electricity consumption
*Based on gross output
Per cents are calculated by the authors

Among BRICS nations, China has been generating maximum amount of electricity, followed by India and Russia. In India, China and South Africa, maximum share of electricity generation is by coal; but in case of Brazil, it is by hydro and in case of Russia, it is by natural gas.

Electricity consumption is significantly positively associated with GDP (correlation coefficient is 0.998, P-Value < 0.001), primary energy consumption (correlation coefficient is 0.998, P-Value < 0.001), CO_2 emissions from energy (correlation coefficient is 0.998, P-Value < 0.001), CO_2 equivalent emissions from energy, process emissions, flaring

(correlation coefficient is 0.997, P-Value < 0.001), oil consumption (correlation coefficient is 0.993, P-Value < 0.001), coal consumption (correlation coefficient is 0.992, P-Value < 0.001), nuclear energy consumption (correlation coefficient is 0.882, P-Value = 0.048), hydroelectricity consumption (correlation coefficient is 0.965, P-Value = 0.008), renewable energy consumption (correlation coefficient is 0.973, P-Value = 0.005).

Increase in income (related data is GDP) is linked with increase in consumption of primary energy including natural gas, oil, coal, renewable energy (nuclear and electricity, etc). Again the increase of energy consumption particularly fossil energy increases in CO_2 emissions from energy, CO_2 equivalent emissions from energy, process emissions and flaring. Different types of energy consumption are highly associated each other.

The study of Pao and Tsai (2010) indicated that fossil energy consumption has a positive impact on emission and economic growth and in order to minimize emissions and not to adversely affect economic growth, enhancing both energy supply investment and energy efficiency and enhancing energy conservation policies to minimize unnecessary wastage of energy can be initiated for energy-dependent BRIC countries.

Fu et al. (2021) examined the relationship between energy use, economic growth and environmental quality.

Bioenergy or biofuel is a type of renewable energy that is produced from recently living organic materials (agricultural or animal) known as biomass, which can be utilized to produce transportation fuels, heat, electricity, and products. Most types of biofuels are biodiesel, bioethanol and biogasoline, etc.

Statistics of biofuels (thousand barrels of oil equivalent daily) production and consumption in BRICS nations in 2021 are provided in the following Table (Table 14).

Table 14. Statistics of biofuels (thousand barrels of oil equivalent daily) production and consumption in some of BRICS nations in 2021

Nation	Production			Consumption			Gap = Production – Consumption
	2021	Growth rate (%) 2020-2021	World share (%) 2021	2021	Growth rate (%) 2020-2021	World share (%) 2021	
Brazil	376	-4.3	21.5	412	5.9	22.4	-36
India	37	59.8	2.3	43	21.0	2.3	-6
China	64	11.4	4.0	48	26.0	2.6	16

Source: bp (2022)

Regarding controlling shortfalls in production compared to consumption of energy, Brazil has remarkable energy policies and is the leading producer of bio-fuels following hydro energy until 2014 but supported wind and solar power development by supporting specific tariffs for energy production from solar and wind.

Russia needs improvement in its regulatory framework with more stimuli in energy policies. In order to augment the production and the scope of consumption of hydrogen as an environmentally friendly energy carrier, as well as Russia's entry into the world leaders in its production and export, the Government of the Russian Federation approved in 2020 the Action Plan "Development of Hydrogen Energy in the Russian Federation Until 2024" and in 2021 - the Concept for the Development of Hydrogen Energy in the Russian Federation.

China is developing upon wind and hydropower but it needs strong policy measures to regulate increased CO_2 emissions and renewable energy targets for covering technologies for electricity.

South Africa requires lessons to enhance renewable energy and reduce coal mining as energy from coal is costly and not environment-friendly.

India needs remodeling in energy policy and added incentives and consumer specific energy policies for research-infrastructure and energy production technologies to increase the portion of non-fossil-based energy resources to 40 percent of installed electric power capacity by 2030, with the help of the transfer of technology and low-cost international finance, including from Green Climate Fund (GCF).

BRICS nations devoted great importance to cooperation in R&D and deployment of clean technologies aiming in enhancing the efficiency of the energy sector, diminishing its environmental impact, including lowering GHG emissions,

and developing new energy sources and carriers. They planned to (a) promote such cooperation in different areas including more efficient utilization of fossil fuels, advancing low or zero-emission energy solutions such as renewable energy, nuclear, hydrogen, advanced bio-energy and others and apply Circular Carbon Economy (CCE) approach and developing Carbon Capture Utilization and Storage (CCUS) capacities.

Moreover, BRICS countries need to rethink their energy policies based upon their respective existing geographical, economic, societal and environmental situations which will assist in framing global energy policies and more financial stability (Pathak & Shah, 2019).

5. Energy imports and exports by BRICS countries

India has around 250 Million Metric Tonnes Per Annum (MMTPA) of refining capacity and is the second largest nation in Asia. Above 60 percent of crude docks in the Gulf of Kutch and Gujarat is making India one of the most planned locations for refineries. India is one of the largest importers of crude oil, also at the same time; it is one of the largest exporters of refined oil; given the existence of refineries to take benefits of the nation's location between crude oil-producing in the Middle East nations and its consumers in the rest of Asia. It exports refined petroleum products to USA, UK and Australia and also to oil-producing nations like Iraq and UAE. The export of petroleum products enhanced from 59.08 MT during 2010-2011 to 65.69 MT during 2019-2020 at a CAGR of 1.19 percent. But, because of an enhancement of domestic consumption combined with several shutdowns in refineries, the export of petroleum products in 2019-2020 reduced by (-) 21.08 percent from the year 2018-2019 (NAYARA ENERGY, n.d.).

Some of energy imports and exports by BRICS countries are provided below. Oil: Trade movements are provided in the following Table (Table 15).

Table 15. Oil: Trade movements (thousand barrels daily)

	2021	Growth rate (%) 2020-2021	World share (%) 2021
		Imports	
China	12,724	-1.6	19.0
India	5,325	8.7	8.0
		Exports	
Russia	8,234	5.9	3.2

Source: bp (2022)

LNG (liquid natural gas) imports and exports are provided in the following Table (Table 16).

Table 16. Natural gas: LNG imports and exports (billion cubic metres)

	2021	Growth rate (%) 2020-2021	World Share (%) 2021
		Imports	
Brazil	10.1	203.8	2.0
China	109.5	16.8	21.2
India	33.6	-8.1	6.5
		Exports	
Russia	39.6	-4.9	7.7

Source: bp (2022)

Coal: Trade movements (exajoules) are provided in the following Table (Table 17).

Table 17. Coal: Trade movements (exajoules)

	2021	Growth rate (%) 2020-2021	World share (%) 2021
		Imports	
China	6.54	-0.8	19.5
India	4.90	3.7	14.5
		Exports	
Russia	5.99	5.9	17.9
South Africa	1.93	11.0	5.8
China	0.29	61.1	0.9

Source: bp (2022)

6. Findings and policy recommendations

BRICS ERCP is an international program for developing energy-based sustainable development, sharing advanced energy technologies. BRICS is a heterogeneous club of nations having around a quarter of GDP, supplying energy products to 40 percent of the world's population. The BRICS report for about 43 percent of CO_2 emissions, 42 percent of energy products from renewable resources and 37 percent of the world's energy consumption.

Remarkable findings from energy data relating to BRICS are as follows:

(a) China consumed 26.5 percent of the world's energy in 2021. India is the third largest energy-consuming nation in the world. Energy consumption in South Africa has decreased over 2011-2021. Fossil energy is the major source of energy.

(b) Primary energy consumption per capita has decreased in South Africa and Brazil over 2011-2021.

(c) Human Development Index (HDI) and Climate Change Performance Index (CCPI) are significantly negatively associated. The economic aspects GDP and HDI are significantly positively associated with energy consumption. CCPI and energy consumption are significantly negatively associated. GDP and energy consumption are significantly positively associated with CO_2 emission.

(d) South Africa is weak in the context of total proved reserves.

(e) China has maximum CO_2 emission.

(f) (1) China, India and South Africa have oil deficit, (2) China, India, Brazil and South Africa have natural gas deficit and (3) India, China and Brazil have coal deficit mentioned in order.

(g) Consumption of nuclear energy, hydroelectricity and renewable energy is highest in China and lowest in South Africa.

(h) Electricity generation is highest in China and lowest in South Africa.

(i) Production and consumption of bio-fuels were obtained for Brazil, India and China. China is having surplus production.

(j) Regarding the controlling the shortfalls in energy production, BRICS members have undertaken some measures.

(k) In trade movements of oil, natural gas and coal; China and Russia are the leading members in imports and exports respectively.

Some of policy recommendations on energy production and consumptions, etc are as follows:

(a) Nuclear hydrogen energy production technologies have great scopes and advantages over other sources which might be considered for enhancing the hydrogen share in a future energy economy.

(b) More emphasis is to be given on energy conversation, energy efficiency, energy security, optimized mix of

usage of energy from nonrenewable and renewable sources preferably with locally appropriate energy production supported by subsidized financing assuring low-carbon emissions.

(c) Shifting towards renewable sources of energy generating electricity and increasing usages of electric (a) transports, (b) heating and cooling equipments, (c) manufacturing and (d) household usages particularly lighting etc.

7. Limitations and future research directions

Since there are only five members in the BRICS family, number of sampling units is very limited. We may only find country wise trend analyses of energy consumptions and compare the trends.

Some of the future researches on energy economics may be conducted on (a) global energy consumption trends and prospects, (b) analysis of global energy production and consumption by sources, (c) socio-economic development and energy economics and (d) comparative study of energy economics among developed and developing countries, etc.

Conflicts of interest

The authors declare that there is no conflict of interest.

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