YEŞİL BÜYÜME: BRICS-T ÜLKELERİNİN YEŞİL BÜYÜME GÖSTERGELERİNİN ENERJİ VERİMLİLİĞİ KAPSAMINDA İNCELENMESİ

GREEN GROWTH: EXAMINING GREEN GROWTH INDICATORS OF BRICS-T COUNTRIES IN THE CONTEXT OF ENERGY PRODUCTIVITY

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ABSTRACT

Green growth is a growth policy that combines the goals of improving environmental quality and increasing economic welfare. Green growth is a multidimensional concept; thus, it is very difficult to determine standard indicators that can be used for its measurement. Different institutions and organizations have proposed some green growth indicators. However, the indicators determined by the OECD are widely used in research for reasons such as addressing a large number of data within the scope of different dimensions and containing easily accessible data over a long period of time. The OECD has divided green growth indicators into five subgroups: natural asset base, policy responses, socioeconomic context, quality of life, and productivity. Energy productivity is one element within the productivity subgroup. This study examines energy productivity in the context of BRICS-T countries using indicators announced by the OECD. BRICS-T countries stand out with their economic growth performance, have large populations, and play an important role in energy production and consumption. Although the share of fossil fuel resources in the energy production of countries is high, this share is starting to decline, and renewable energy investments are gradually increasing. In order to sustain the green growth process that has been initiated, countries need to increase their energy transformation performance and energy productivity. In this study, data from BRICS-T countries between 1990 and 2023 were comparatively examined and future policy recommendations were made. The indicators examined are energy intensity, energy productivity, total energy supply, the share of renewable energy supply in total energy supply, and the share of renewable electricity generation in total electricity generation. In all countries within the group, an increase in energy intensity is observed over time. The increase in energy intensity reflects the decrease in energy productivity. Therefore, countries should focus on policies to reduce their energy intensity. The share of renewable electricity generation and energy supply in Brazil is higher than in other countries in this group. However, this does not apply to other countries. Other countries in the group, including Türkiye, should focus on using more renewable resources for electricity generation and total energy supply. For this purpose, incentive systems should be created to support renewable energy investments, financial support should be provided to investors, and companies and consumers' awareness of the importance of renewable energy should be raised. In renewable energy investments, cooperation between the public and private sectors should be ensured. In

this way, countries can accelerate the energy transition process and make it easier to achieve their green growth goals by increasing their energy productivity.

Keywords: Green growth, energy productivity, energy transition, renewable energy, BRICS-T

ÖZET

Yeşil büyüme, çevre kalitesinin iyileştirilmesi ve ekonomik refahın artırılması hedeflerinin bir arada yürütüldüğü bir büyüme politikasıdır. Yeşil büyüme, çok boyutlu bir kavram olduğu için ölçümünde kullanılabilecek standart göstergelerin belirlenmesi oldukça zordur. Farklı kurum ve kuruluşların önerdiği yeşil büyüme göstergeleri vardır. Ancak farklı boyutlar kapsamında çok sayıda veriyi ele alması, uzun bir zaman dilimine ait kolay ulaşılabilecek verileri içermesi gibi nedenlerle OECD tarafından belirlenen göstergeler araştırmalarda yaygın olarak kullanılmaktadır. OECD yeşil büyümeye ait göstergeleri beş alt gruba ayırmıştır. Bunlar doğal varlık tabanı, politika tepkileri, sosyo-ekonomik bağlam, yaşam kalitesi ve verimliliktir. Enerji verimliliği, verimlilik alt grubunun içinde bulunan unsurlardan biridir. Bu çalışma OECD tarafından açıklanan göstergeleri kullanarak enerji verimliliğini BRICS-T ülkeleri bağlamında incelemektedir. BRICS-T ülkeleri ekonomik büyüme performansları ile ön plana çıkan, kalabalık nüfusa sahip, enerji üretimi ve tüketiminde önemli rol oynayan ülkelerdir. Ülkelerin enerji üretimlerinde fosil kaynakların payı yüksek olsa da bu payın gerilemeye başladığı ve yenilenebilir enerji yatırımlarının giderek yükseldiği görülmektedir. Başlatılan yeşil büyüme sürecinin sürdürülmesi için ülkelerin enerji dönüşümüne ait performanslarını ve enerji verimliliklerini artırmaları önem arz etmektedir. Çalışmada BRICS-T ülkelerinin 1990-2023 yılları arasındaki verileri karşılaştırmalı olarak incelenerek geleceğe yönelik politika önerilerinde bunulmuştur. İncelenen göstergeler enerji yoğunluğu, enerji verimliliği, toplam enerji arzı, yenilenebilir enerji arzının toplam enerji arzı içindeki payı ve yenilenebilir elektrik üretiminin toplam elektrik üretimi içindeki payıdır. Grup içinde yer alan bütün ülkelerde özellikle enerji yoğunluğunda zaman içinde artış gözlenmektedir. Enerji yoğunluğunun artması, enerji verimliliğinin azalmakta olduğunu yansıtır. Bu nedenle ülkeler enerji yoğunluklarını azaltacak politikalara yönelmelidirler. Brezilya'da yenilenebilir elektrik üretiminin ve yenilenebilir enerji arzının payı gruptaki diğer ülkelere kıyasla daha yüksektir. Ancak bu durum diğer ülkeler için geçerli değildir. Türkiye de dahil olmak üzere gruptaki diğer ülkeler elektrik üretiminde ve toplam enerji arzında yenilenebilir kaynakları daha fazla kullanmaya yönelmelidirler. Bunun için yenilenebilir enerji yatırımlarını destekleyecek teşvik sistemleri oluşturulmalı, yatırımcılara finansman desteği sağlanmalı, yenilenebilir enerjinin önemi konusunda firmaların ve tüketicilerin bilinç yüzeyleri yükseltilmelidir. Yenilenebilir enerji yatırımlarında kamu ile özel sektör arasında iş birliği sağlanmalıdır. Böylece enerji verimliliklerinde artış sağlayarak hem enerji dönüşüm sürecini hızlandırabilirler hem de yeşil büyüme amaçlarına ulaşmayı kolaylaştırabilirler.

Anahtar kelimeler: Yeşil büyüme, enerji verimliliği, enerji dönüşümü, yenilenebilir enerji, BRICS-T

INTRODUCTION

Green growth is a concept that expresses the harmonious pursuit of economic and environmental goals. While reducing environmental pollution is considered in the green growth process, efforts to increase economic welfare are not ignored. Therefore, within the scope of green growth policies, efforts are being made to simultaneously increase economic growth and environmental quality. Different organizations have announced various indicators to monitor and evaluate the green growth performance of countries. However, since green growth is a comprehensive and multidimensional concept, there is no absolute set of indicators that can be used to measure it. In this study, indicators determined by the OECD were used. The OECD has divided green growth indicators into 5 subgroups. These groups are the natural asset base, policy responses, socioeconomic factors, quality of life, and productivity. Each subgroup contains different indicators. The OECD examines productivity within the scope of environmental and resource productivity. Within the scope of productivity, four subgroups were determined: CO2 productivity, energy productivity, non-energy material productivity, and environmentally adjusted multi-factor productivity. Focusing on energy productivity, the study compared BRICS-T countries in terms of energy productivity with the help of various indicators. BRICS-T countries include Brazil, Russia, India, China, South Africa, and Turkiye. These countries have large populations, large foreign trade volumes, and high growth rates. The high production amounts of goods and services also increases the energy demand of these countries. Which energy sources are used to meet the increasing energy demand and whether energy resources are used efficiently are of great importance in terms of sustainability and green growth. Therefore, increasing energy productivity in BRICS-T countries can be beneficial not only these countries but also environmental pollution, energy transformation, and green growth processes worldwide. For this purpose, the energy productivity indicators of the BRICS-T countries were examined for the period 1990-2023. First, the concept of green growth was explained, and information about green growth indicators was provided. Within the scope of energy productivity, energy density, energy productivity, total energy supply, share of renewable energy supply, and share of renewable electricity generation were examined. The last section includes policy recommendations that can be implemented to increase energy efficiency.

GREEN GROWTH CONCEPT

With the industrial revolution, rapid changes have occurred in the production process. Because of the industrial revolution, mass production began, and the production of goods and services increased. The increase in the production of goods and services has increased environmental problems by requiring the use of more energy and resources. Fossil fuels such as coal and oil are extensively used in mass production processes initiated by the industrial revolution. This has led to both rapid depletion of resources and increased environmental pollution (Abid, Ceci, & Ikram, 2022). Although environmental damage caused by rapid economic growth has been ignored for many years, environmental awareness has increased,

especially in recent years. Concerns about the damage caused by increased environmental pollution to human health, ecosystem balance, and natural resource stock have become increasingly widespread. The importance of environmental awareness, which began to be expressed by different segments of society in the 1960s and 1970s, was concretely demonstrated in the international arena through a report published in 1972. The report, published by the Club of Rome and titled "The Limits to Growth," has an important place on the path to the concept of sustainable development. After this report was published, international efforts to protect the environment followed one another. The Brundtland Report was published in 1987, and the term "sustainable development" was defined for the first time (Abeysekera, 2022). At the Rio Conference held in 1992, national efforts were stated to achieve sustainable development, and countries were advised to develop their own strategies. In 2015, the United Nations Conference on Sustainable Development was held, and 17 goals, known as the Sustainable Development Goals, were established (Henderson and Loreau, 2023).

Sustainable development is a comprehensive concept with economic, social, and environmental dimensions. There is a need for policies that will facilitate the achievement of sustainable development goals by addressing all dimensions of sustainable development together. In line with this need, the concept of "green growth" has emerged and has become one of the main strategies for most countries (He and Du, 2022). Today, policymakers in most developed and developing countries adopt the green growth approach and shape their growth policies in line with this approach. Green growth is defined in different ways, from different sources, and by different institutions and organizations. There is no single absolute definition (Hassan et al., 2023). However, three different institutions come to the fore in the definition of green growth, especially in the literature. These institutions are the World Bank, the United Nations Environment Programme (UNEP), and the Organization for Economic Co-operation and Development (OECD). The World Bank emphasizes the importance of environmental management and natural capital when defining green growth. According to the World Bank definition, green growth refers to a type of growth that is efficient, clean, and durable. Green growth is efficient because it ensures productivity in the use of natural resources, clean because it minimizes environmental pollution, and durable because it takes natural disasters into account (Hickel and Kallis, 2020). The definition established by the OECD emphasizes that green growth helps achieve economic and environmental goals simultaneously. Green growth ensures high sustainable growth rates while also supporting environmental protection. Green growth reduces the negative effects of climate change, prevents a decrease in biodiversity, ensures conscious consumption of natural resources, and increases resource productivity. While doing so, it does not neglect economic growth and development. Therefore, the OECD's definition of green growth draws attention to the harmony between economic and environmental policies (Houssini and Geng, 2022). This definition reveals the multidimensional nature of environmental issues. Environmental problems are too complex to be solved by one-way policies. In order to solve environmental problems, environmental

policies and economic and social policies must be implemented simultaneously and in harmony. In other words, economic policies cannot be ignored when solving environmental problems. Economic policies should not be developed without considering their environmental consequences. The definition established by the OECD is important because it expresses the interplay between economic and environmental policies (Tawiah, Zakari, & Adedoyin, 2021). UNEP, on the other hand, prefers to use the concept of green economy instead of green growth. When defining the green economy, the UNEP emphasizes the connection between increasing income, welfare, and protecting the environment. According to the UNEP, a green economy increases income levels and enables people to live a well-off life. This approach simultaneously reduces environmental risks, increases resource productivity, and helps establish ecological balances (Chaaben et al., 2024).

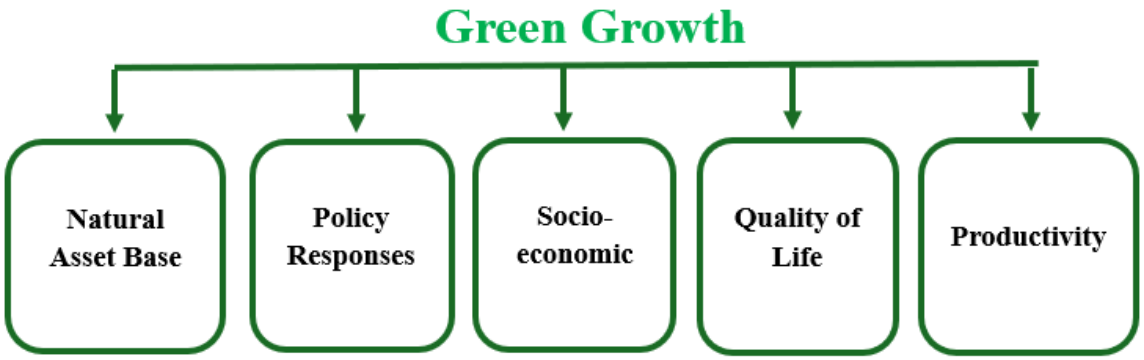
As can be seen from the definitions of green growth, it has various economic, social, and environmental functions. Green growth helps use natural resources in ways that enhance human well-being. Reduces dependence on polluting industries and encourages the development of new technologies that will increase low-carbon production. This enables the shift of resources toward low-carbon rather than high-carbon industries. Thus, it increases environmental quality by reducing carbon emissions. While doing so, it does not neglect sustainable economic growth and aims for high and sustainable growth rates (Zhao et al., 2023). However, technological change and renewable energy play an important role in activating these functions of green growth. Because the main purpose of green growth is to increase environmental quality while ensuring sustainable economic growth. Energy is needed to increase economic growth. Energy is a basic input to the production of goods and services. If the use of renewable energy sources is increased instead of fossil fuels, more goods and services can be produced, and environmental quality can be improved. The place and importance of renewable energy sources in improving environmental quality cannot be ignored. Renewable energy sources not only reduce environmental pollution but also reduce external dependency on energy and help increase energy security. For the use of renewable energy sources, new technologies need to be developed. Therefore, energy productivity and renewable energy are important elements of green growth (Wei, Jiandong, & Saleem, 2023).

GREEN GROWTH INDICATORS

Determining indicators of green growth is of great importance, especially for policymakers. When determining decisions to be taken in the green growth process, it is necessary to provide comprehensive and accurate information. The indicators to be used in evaluating policy outcomes and comparing countries' green growth performance should be decided. However, since green growth is a relatively new and comprehensive concept, no clear indicators exist for it. It is intertwined with different concepts such as resource productivity, ecological productivity, sustainable development, and the circular economy. It is therefore difficult to establish a generally accepted data set for green growth. Despite the difficulties experienced, various institutions, organizations, and researchers are creating datasets that will

help us examine green growth (Lyytimaki et al., 2018). Organizations such as the OECD, the UNEP, the Global Green Growth Institute, and the Green Growth Knowledge Platform suggest indicators to measure and evaluate green growth (Datta, 2024). The OECD created the first data set for monitoring the green growth process in 2011. In its report titled "Toward Green Growth: Monitoring Progress", the OECD proposed various indicators under four main groups to examine green growth. In 2014, it updated the indicators by publishing a new report. OECD indicators are widely used in studies in the literature for reasons such as addressing green growth in different dimensions, providing a wide set of indicators, and suggesting easily accessible data (Sarkodie, Owusu, & Taden, 2023).

In this study, an examination was made within the scope of OECD's green growth indicators. Figure 1 presents the OECD's green growth indicators. As can be seen from the figure, the OECD divided the green growth indicators into five subdimensions. The natural asset base, policy responses, socioeconomic context, quality of life, and productivity are identified. Each dimension is divided into subgroups and explained with the help of different indicators.



Source: Sarkodie et al., 2023.

Figure 1. OECD's green growth indicators

This study focused on the productivity dimension. The OECD productivity dimension is divided into four groups: CO2 productivity, energy productivity, non-energy material productivity, and environmentally adjusted multi-factor productivity. For each group, an examination is carried out using different indicators (OECD, 2017; Sarkodie et al., 2023). As can be seen, energy productivity is a sub-branch of the productivity dimension. Energy productivity is essential for both economic and environmental purposes. Energy is one of the basic inputs to the production of goods and services. However, fossil resources used in energy production are scarce, have a limited lifespan, and their use causes environmental pollution. Countries should both use their existing energy resources in the most efficient way and turn to alternative energy sources. Using renewable energy sources instead of fossil fuels can help reduce problems related to energy supply, energy security, and environmental pollution (Maradin, 2021).

ENERGY PRODUCTIVITY IN BRICS-T COUNTRIES

The BRICS-T countries are Brazil, Russia, India, China, South Africa and Türkiye. In 2006, a group of countries known as the BRIC emerged, consisting of four countries: Brazil, Russia, India, and China. South Africa was included in this group in 2010. Thus, the name of the group began to be expressed as BRICS (Karakurt, 2021). However, since Türkiye's economic and demographic characteristics are similar to the other countries in the group, with the addition of Türkiye to the group, a group of six countries known as BRICS-T countries entered the literature. BRICS-T countries are countries with development potential due to their crowded and young population structure, high growth rates, and high share of world trade. Russia, Brazil, and South Africa are rich in natural resources. Türkiye stands out for its geopolitical location and the breadth of its logistics networks. China and India are among the leading countries in the world in the production of goods and services, with their production facilities (Tekbaş, 2021). It is expected that countries in the group will further increase their growth potential in the future due to their characteristics and advantages. In order for countries to maintain rapid and high growth rates, they need to use their production factors effectively and efficiently. As a basic input to production activities, it is extremely important to use energy efficiently and increase energy productivity (Fendoğlu, 2021). For this reason, in this study, the BRICS-T countries were examined in terms of energy productivity, and a comparison was made between the countries. In this way, recommendations can be made on which policies should be implemented by drawing attention to the indicators that a country needs to improve. The indicators examined within the scope of energy productivity are energy density, energy productivity, total energy supply, the share of renewable energy supply in total energy supply, and the share of renewable electricity generation in total electricity generation.

Energy intensity is an important indicator for comparing countries' energy productivity. Energy intensity refers to the amount of energy used to produce a unit of good. Increasing energy intensity indicates that a unit of goods is produced using more energy, and the energy productivity decreases. Therefore, countries aim to reduce their energy intensity. Increasing energy density indicates that energy is not being efficiently used. Table 1 shows the energy intensities of BRICS-T countries. According to the information in the table, the country with the highest energy intensity is Russia. Compared with the other five countries, Russia lags behind in terms of efficient energy use. Between 1990 and 2022, the only year in which energy intensity was less than 4 in Russia was 1998. In other years, energy intensity was above 4 and in some years, above 5. In Brazil, energy intensity was below one between 1990 and 1994 and was recorded as 1 in 1995. In 1996 and later, it exceeded 1. The increasing energy intensity trend in Brazil indicates that energy productivity is decreasing. A similar situation is observed in India, China and Türkiye. The energy density in India, which was 0.32 in 1990, increased to over 0.4, 0.5, and 0.6 in the following years. The value was calculated as 0.72 in 2022, which is the highest energy intensity value between 1990 and 2022. In China, energy intensity was below one between 1990 and 2002 and exceeded one

between 2003 and 2010. Between 2011 and 2022, energy intensity is higher than 2. In 2022, the energy intensity in China was 2.66 percent. Although the energy intensity in Türkiye was below one between 1990 and 1994, there was an increase in energy intensity in the following years. Although the energy density did not exceed 2 in the studied period, it was generally greater than 1.1. Energy intensity in Türkiye exceeded 1.8 in 2021, 2022, and 2023. Between 1990 and 2022, the lowest value of energy intensity in South Africa was 2.03, and the highest value was 2.80 in 2008. In other years, the energy intensity fluctuated between these values, but notably in South Africa, the energy intensity did not fall below 2. According to the data examined, energy intensity in the BRICS-T countries has generally increased over time. This leads to a decrease in energy productivity.

Table 1. Energy Intensity (Tonnes of oil equivalent per person)

Years	Brazil	Russia	India	China	South Africa	Türkiye
1990	0,94	5,94	0,32	0,76	2,25	0,93
1991	0,94	5,87	0,33	0,72	2,25	0,90
1992	0,94	5,36	0,33	0,74	2,10	0,93
1993	0,95	5,06	0,34	0,78	2,20	0,97
1994	0,98	4,43	0,35	0,81	2,27	0,95
1995	1,00	4,29	0,36	0,86	2,35	1,02
1996	1,04	4,25	0,37	0,87	2,39	1,10
1997	1,08	4,07	0,38	0,87	2,40	1,13
1998	1,09	3,98	0,38	0,86	2,42	1,13
1999	1,10	4,14	0,39	0,88	2,35	1,10
2000	1,08	4,22	0,39	0,90	2,26	1,19
2001	1,09	4,29	0,39	0,92	2,17	1,08
2002	1,10	4,29	0,40	0,97	2,12	1,12
2003	1,11	4,46	0,40	1,10	2,36	1,18
2004	1,16	4,50	0,42	1,25	2,55	1,19
2005	1,17	4,55	0,43	1,37	2,44	1,23
2006	1,20	4,71	0,44	1,48	2,46	1,34
2007	1,25	4,73	0,46	1,59	2,64	1,43
2008	1,31	4,85	0,48	1,62	2,80	1,39
2009	1,25	4,56	0,51	1,72	2,79	1,36
2010	1,37	4,87	0,53	1,88	2,56	1,45
2011	1,38	5,01	0,55	2,01	2,57	1,52
2012	1,42	5,06	0,57	2,06	2,43	1,57
2013	1,47	4,91	0,58	2,12	2,37	1,51
2014	1,51	4,91	0,61	2,15	2,48	1,54
2015	1,46	4,73	0,62	2,15	2,30	1,65
2016	1,40	4,86	0,63	2,13	2,35	1,72
2017	1,41	4,95	0,65	2,19	2,30	1,83
2018	1,38	5,21	0,67	2,29	2,21	1,77
2019	1,39	5,02	0,67	2,38	2,26	1,77
2020	1,36	5,00	0,63	2,45	2,05	1,76
2021	1,40	5,64	0,68	2,61	2,08	1,89
2022	1,40	5,56	0,72	2,66	2,03	1,84
2023	1,44	-	-	-	-	1,83

Source: OECD Data Explorer.

Energy productivity expresses the value of GDP produced per unit of energy. Increasing energy productivity is essential for countries. Countries aim to increase energy productivity

while aiming to reduce energy intensity. Table 2 presents the energy productivity indicators of BRICS-T countries. Energy productivity in Türkiye is higher than in other BRICS-T countries. Energy productivity in Türkiye did not fall below 12.000 USD between 1990 and 2023. Energy productivity is usually over 13.000 USD. Energy productivity in Türkiye has been on an increasing trend between 1990 and 2023, and Türkiye achieved its highest energy productivity in 2023 during this period. The energy productivity in 2023 was calculated as 18.477,12 USD. China's energy productivity has also gradually increased over time. The energy productivity in China in 1990 was 1.936,63 USD. With an increase in the following years, energy productivity exceeded 7000 USD. The energy productivity in China was USD 7.016,03 and USD 7.076,48 in 2021 and 2022, respectively. Energy productivity in South Africa was between 4.000 and 5.000 USD between 1990 and 2001. It was calculated as USD 5.258,52 in 2002. Although there were years between 2003 and 2009 when energy productivity again fell below 5.000 USD, it did not fall below 5.000 USD in 2010 and thereafter. It even exceeded 6.000 USD. In 2022, energy productivity in South Africa reached its highest value between 1990 and 2022 at USD 6.412,40. Energy productivity is higher in India than in China and South Africa. Between 1990 and 1995, energy productivity in India was over 5.000 USD. Higher levels of energy productivity were achieved in the following years. For example, between 2003 and 2010, energy productivity exceeded 7.000 USD. It rose even further in the 2016-2021 period, reaching values higher than USD 9.000. Energy productivity in Russia has followed a fluctuating course with increases and decreases between 1990 and 2022. Between 1990 and 2003, energy productivity was over 3.000 USD. After 2003, there were years when energy productivity exceeded 5.000 USD and then dropped back to 4.000 USD. The energy productivity in Russia was 5.113,34 USD in 2019, whereas it is 3.722,32 USD and 3.254,87 USD in 2021 and 2022, respectively. When examining energy productivity values in Brazil, it is striking that there was a significant and rapid decline, especially between 1990 and 1994. During this period, energy productivity decreased significantly each year compared to the previous year. This was due to the high inflation and debt crisis that Brazil experienced in the 1980s continuing into the early 1990s. Between 1995 and 2021, energy productivity was more stable with no major fluctuations. Between 1995 and 2021, energy productivity is above 10.000 USD and below 11.000 USD. In 2022 and 2023, it fell below 10.000 USD. In 2023, energy productivity in Brazil was estimated to be 8.662,68 USD.

Table 2. Energy Productivity (US dollars per tonne of oil equivalent, 2015)

Years	Brazil	Russia	India	China	South Africa	Türkiye
1990	1.143.816.081,10	3.665,30	5.611,47	1.936,63	4.523,77	13.099,16
1991	208.591.691,73	3.512,13	5.422,00	2.180,00	4.357,56	13.445,30
1992	17.612.845,17	3.286,34	5.516,11	2.408,21	4.473,94	13.637,86
1993	677.472,82	3.180,05	5.611,33	2.589,09	4.248,09	13.818,33
1994	22.214,29	3.178,83	5.716,53	2.794,35	4.183,75	13.226,15
1995	10.788,62	3.144,20	5.856,07	2.887,67	4.089,54	12.957,84
1996	10.594,05	3.056,85	6.003,61	3.088,38	4.143,50	12.701,59
1997	10.458,34	3.245,06	5.988,19	3.374,98	4.169,87	13.016,99
1998	10.245,82	3.146,49	6.203,21	3.621,68	4.111,68	13.219,09
1999	10.060,53	3.232,04	6.395,72	3.827,46	4.283,60	12.981,77
2000	10.445,45	3.496,51	6.485,51	4.025,62	4.585,72	12.692,84
2001	10.409,30	3.636,30	6.700,52	4.221,28	4.859,48	12.989,73
2002	10.434,23	3.823,41	6.763,79	4.332,77	5.258,52	13.085,24
2003	10.389,27	3.966,08	7.126,41	4.181,29	4.819,05	13.057,95
2004	10.369,85	4.237,76	7.259,74	4.043,92	4.626,31	13.976,16
2005	10.480,19	4.479,65	7.523,97	4.086,74	5.037,48	14.639,20
2006	10.525,00	4.709,46	7.650,43	4.210,98	5.210,63	14.129,14
2007	10.553,26	5.095,34	7.838,30	4.468,95	5.053,46	13.768,87
2008	10.475,73	5.238,21	7.650,47	4.771,84	4.849,98	14.149,27
2009	10.859,20	5.140,71	7.661,63	4.895,54	4.716,04	13.487,49
2010	10.556,91	5.010,98	7.863,44	4.905,05	5.220,38	13.593,28
2011	10.857,86	4.713,66	8.015,13	5.006,81	5.280,73	14.203,04
2012	10.614,91	4.840,87	7.996,71	5.213,42	5.645,01	14.212,39
2013	10.469,29	5.070,81	8.308,30	5.443,06	5.820,03	15.791,16
2014	10.204,38	5.095,49	8.336,98	5.702,49	5.567,61	16.006,93
2015	10.030,00	5.094,73	8.732,69	6.076,36	5.973,72	15.700,26
2016	10.058,45	4.954,38	9.280,35	6.530,81	5.813,74	15.284,01
2017	10.022,72	4.953,06	9.454,43	6.731,36	5.915,47	15.300,76
2018	10.328,84	4.836,11	9.605,53	6.857,21	6.169,98	16.047,57
2019	10.295,21	5.113,34	9.962,39	6.958,57	5.954,25	15.923,56
2020	10.134,41	4.989,42	9.889,48	6.899,00	6.095,06	16.174,17
2021	10.226,40	3.722,32	9.914,27	7.016,03	6.209,26	16.610,84
2022	9.398,90	3.254,87	8.752,80	7.076,48	6.412,40	17.858,47
2023	8.662,68	-	-	-	-	18.477,12

Source: OECD Data Explorer.

Table 3 shows the total energy supply data of BRICS-T countries between 1990 and 2023. China is the country with the highest total energy supply. Compared to the other five countries, China clearly stands out. China's total energy supply has gradually increased over time. In 1990, China's total energy supply was 873.64 million tons. The value reached 1,044.45 million tons in 1995, 2,097.52 million tons in 2007, and 3,092.43 million tons in 2017. China's total energy supply in 2023 was 3,799.54 million tons, the highest among all countries between 1990 and 2023. Although India's total energy supply is lower than China's, it has increased over time. The total energy supply in India was less than 300 million tons in 1991 and 1992. In the following years, the total energy supply first exceeded 300 million tons, and then it exceeded 500 and 600 million tons. In 2012 and 2013, the total energy supply in India exceeded 700 million tons and was 730.06 million tons and 747.55 million tons, respectively. The increase continued in subsequent years. India's total energy supply in 2023

is 1,015.25 million tonnes in 2023. The total energy supply in Russia generally fluctuated between 600 and 800 million tons between 1990 and 2023. During the period under review, the only year in which the total energy supply fell below 600 million tons was 1998. The total energy supply in 1998 was 588.06 million tons. The years when the total energy supply was over 800 million tons were 1990, 1991, 2021, and 2022. The total energy supply in Russia was 822.36 million tons in 2021 and 807.88 million tons in 2022. It can be stated that the total energy supply in Brazil is less than that in China, India, and Russia. Although the total energy supply has increased over time, this increase has been relatively limited. The total energy supply in Brazil was below 200 million tons between 1990 and 2002. The total energy supply exceeded 200 million tons in 2003, reaching 200.13 million tons. In 2014, it reached 303.68 million tons in 2014. Afterwards, it fell below 300 million tonnes and did not exceed 300 million between 2015 and 2021. In 2022 and 2023, there was an increase in the total energy supply. In 2023, the total energy supply in Brazil was 311.92 million tons, the highest amount of energy supply in the period examined.

Among the BRICS-T countries, the two countries with the lowest total energy supply are South Africa and Türkiye. In the period 1990-2014, total energy supply was higher in South Africa compared to Türkiye. Therefore, Türkiye is the BRICS-T country with the lowest total energy supply between 1990 and 2014. As of 2015 and onwards, Türkiye's total energy supply is greater than South Africa's. The total energy supply in Türkiye was less than 100 million tons between 1990 and 2006. In 2007, it was 100.32 million tons in 2007. Although it fell below 100 million tons again in 2008 and 2009, there was no significant decrease; this decrease was due to the global crisis. The total energy supply has gradually increased since 2010. The total energy supply in Türkiye in 2021, 2022, and 2023 is more than 150 million tons.

Table 3. Total Energy Supply (Tonnes of oil equivalent, Millions)

Years	Brazil	Russia	India	China	South Africa	Türkiye
1990	140,54	879,33	280,17	873,64	89,72	51,44
1991	143,12	871,37	293,02	848,00	92,19	50,58
1992	144,62	795,73	303,81	876,83	87,87	52,85
1993	148,25	751,22	312,85	928,80	93,69	56,35
1994	156,09	657,04	327,54	972,77	98,17	55,66
1995	161,54	636,76	347,46	1.044,45	103,55	60,90
1996	170,09	630,36	360,39	1.073,47	106,59	66,48
1997	178,71	602,11	376,00	1.073,05	108,67	69,75
1998	183,07	588,06	385,48	1.078,41	110,76	70,81
1999	187,31	609,14	408,09	1.098,61	108,87	69,75
2000	188,18	619,37	417,86	1.133,21	105,97	76,29
2001	191,64	625,93	424,10	1.170,77	102,70	70,26
2002	196,96	623,28	436,13	1.244,83	98,41	74,24
2003	200,13	645,40	446,39	1.419,41	110,56	78,68
2004	211,39	647,51	471,98	1.616,06	120,41	80,72
2005	216,77	651,75	491,16	1.781,33	116,52	83,99
2006	224,37	670,78	518,16	1.948,70	118,85	93,07
2007	237,04	672,68	549,14	2.097,52	129,12	100,32
2008	250,23	688,36	581,68	2.153,95	138,83	98,42

2009	241,80	646,70	624,34	2.296,86	140,58	98,27
2010	267,50	693,30	661,37	2.536,22	130,86	105,72
2011	270,77	715,70	690,50	2.721,98	133,46	112,51
2012	281,44	724,93	730,06	2.819,68	127,84	117,82
2013	294,48	704,21	747,55	2.910,46	127,08	115,04
2014	303,68	705,96	800,19	2.984,34	134,71	119,10
2015	298,02	692,13	825,01	2.997,93	127,22	128,81
2016	286,84	713,12	840,42	2.980,35	131,59	136,72
2017	292,45	726,33	881,01	3.092,43	130,82	146,81
2018	288,59	764,78	923,11	3.240,58	127,38	144,20
2019	293,05	736,74	924,50	3.383,40	132,33	146,51
2020	287,08	732,74	876,44	3.489,01	121,57	146,92
2021	299,01	822,36	954,99	3.720,66	124,94	159,43
2022	300,53	807,88	1.015,25	3.799,54	123,30	156,50
2023	311,92	-	-	-	-	158,09

Source: OECD Data Explorer.

Table 4 presents the renewable energy supply data of the BRICS-T countries. The data show the share of renewable energy supplied by renewable energy sources in terms of the total energy supply. The table covers the years 1990-2023. However, since 2023 data for Russia, India, China, and South Africa are not available, these data could not be added to the table. As can be seen from the table, Russia is the country with the lowest share of renewable energy in energy supply. Although there were years between 1990 and 2001 when the share of renewable energy supply in Russia was above 3% between 1990 and 2001, this rate did not exceed 3% in 2002 and thereafter. In China and South Africa, the share of renewable energy supply has decreased over time. While the share of renewable energy supply in China was over 20% in the 1990s, it has decreased over time, first falling to 20% and then to below 10%. In 2022, the share of renewable energy supply increased above 10%, reaching 10.35%. In South Africa, renewable energy supply was over 10% between 1990 and 1999, but it fell below 10% since 2000. It fell below 5% between 2017 and 2022. Brazil is the country with the highest share of renewable energy supply energy supply among the BRICS-T countries. The share of renewable energy supply in Brazil was generally above 40% during the period 1990-2023. Even if there are years in which it falls below 40%, these years are few. The share of renewable energy supply approached 50% in 2022 and 2023. Although the share of renewable energy supply in India has decreased over time, the share of renewable energy supply is quite high compared to other countries, except Brazil. The share of renewable energy supply in India was 40.72% in 1990. The only year in which the share of renewable energy supply was above 40% was 1990. This ratio decreased in the following years. It fell below 25% in 2021 and 2022. The share of renewable energy supply in Türkiye is between 10-20% in the 1990-2023 period. The share of renewable energy supply was 18.78% in 1990. The rate increased to 19.05% in 1991. However, a decrease occurred in the following years, and the share of renewable energy supply fell below 10%. It was below 10% in 2007, 2008, and 2011. It can be seen that there was an increase after 2011. In 2022 and 2023, the share of renewable energy supply in Türkiye was 16.96% and 17.35%, respectively.

Table 4. Renewable Energy Supply (Percentage of Energy Supply, %)

Years	Brazil	Russia	India	China	South Africa	Türkiye
1990	46,70	3,01	40,72	24,19	11,70	18,78
1991	46,08	2,98	39,61	25,14	11,71	19,05
1992	45,50	3,21	38,46	24,52	12,36	18,92
1993	44,99	3,36	37,96	23,45	11,74	18,85
1994	44,91	3,35	37,34	22,58	11,50	18,65
1995	43,08	3,35	35,28	21,30	11,09	17,69
1996	41,47	2,93	34,74	20,70	11,02	16,89
1997	40,85	3,00	33,93	20,83	11,04	16,10
1998	40,29	2,96	33,64	20,63	10,99	16,21
1999	40,17	3,09	32,14	20,17	11,01	15,34
2000	38,72	2,91	31,68	19,41	7,16	13,24
2001	37,22	3,00	31,66	18,54	7,48	13,35
2002	39,23	2,84	30,87	17,35	8,37	13,53
2003	41,78	2,67	30,76	14,77	6,88	12,74
2004	42,08	2,92	29,89	12,89	6,07	13,36
2005	42,72	2,87	29,65	11,67	6,25	12,06
2006	43,11	2,81	29,01	10,79	6,00	11,13
2007	44,19	2,88	28,14	9,74	5,14	9,57
2008	44,20	2,58	26,79	9,49	4,71	9,46
2009	45,57	2,83	25,28	8,91	4,46	10,09
2010	43,66	2,55	24,67	8,15	4,40	11,00
2011	42,56	2,48	24,20	7,45	4,22	9,97
2012	40,78	2,46	23,21	7,68	4,34	10,32
2013	39,40	2,66	23,58	7,75	4,38	11,38
2014	38,76	2,55	22,59	8,15	3,99	10,13
2015	40,55	2,53	22,35	8,45	4,11	12,16
2016	42,67	2,66	22,99	8,90	3,83	12,53
2017	42,41	2,58	23,07	9,17	4,26	12,08
2018	44,89	2,53	22,98	9,35	4,49	13,25
2019	45,75	2,71	23,32	9,54	4,21	15,93
2020	47,99	2,94	25,32	9,75	4,49	16,39
2021	44,13	2,68	24,19	9,93	4,54	15,19
2022	47,06	2,53	23,83	10,35	4,71	16,96
2023	48,73	--	--	--	--	17,35

Source: OECD Data Explorer.

Table 5 presents data on electricity generation. It can be seen from the table how the share of electricity generation from renewable energy electricity generation has changed between 1990 and 2023. Among the BRICS-T countries, the country with the highest share of renewable electricity generation is Brazil, while the country with the lowest share is South Africa. The share of renewable electricity generation in Brazil was over 90% between 1990 and 1999. Between 2000 and 2012, the share of renewable electricity generation was between 80% and 90%. Although this rate fell below 80% in the next five years, it is still quite high compared to other BRICS-T countries. The share of renewable electricity generation in Brazil in 2022 and 2023 is 87.68% and 88.99%, respectively. When comparing BRICS-T countries in terms of renewable electricity generation, Brazil clearly outperforms other countries.

South Africa has the lowest share of renewable electricity generation electricity generation among the BRICS-T countries. Despite this, it should not be ignored that the share of

renewable electricity generation has increased over time. Between 1990 and 2014, the share of renewable electricity generation in South Africa was less than 2%. A rapid increase occurred in 2014 and thereafter. The share of renewable electricity generation was 2.32% in 2014, this rate was 8.43% in 2022, and 9.25% in 2023.

The share of renewable electricity generation in Türkiye is higher than in Russia, India, and China. Between 1990 and 2023, the share of renewable electricity generation in Türkiye has followed a fluctuating course. There are years when this share is above 40%, and there are also years when it falls below 30% and 20%. Between 1990 and 2023, the year with the lowest share of renewable electricity generation in Türkiye was 2008, with a rate of 17.35%. The share of renewable electricity generation in Russia is generally between 15% and 20%. Between 1990 and 2022, the share of renewable electricity generation exceeded 20% only in 1994 and 1995. The share of renewable electricity generation in these years was 20.01% and 20.43%, respectively. A similar situation applies to India. Although the number of years in which the share of renewable electricity generation was above 20% was higher in India than in Russia, this share remained mostly below 20% in the period 1990-2023. However, unlike Russia, India had a share of renewable electricity generation below 15% in the past few years. Between 2000 and 2004, the share of renewable electricity generation in India was 13.61%, 13.19%, 12.11%, 13.43%, and 14.66%, respectively. The share of renewable electricity generation in China was 20.41% in 1990. This share remained below 20% between 1991 and 2012. However, a gradual decline occurred in 2013 and later. In fact, the share of renewable electricity generation in China exceeded 30% in 2022 and 2023. The share of renewable electricity generation in China was 30.65% in 2023. This rate is the highest rate achieved in the 1990-2023 period.

Table 5. Renewable Electricity Generation (Percentage of Electricity Generation, %)

Years	Brazil	Russia	India	China	South Africa	Türkiye
1990	94,50	15,34	24,77	20,41	0,61	40,37
1991	94,63	15,69	23,07	18,47	1,19	37,85
1992	94,42	17,05	21,03	17,58	0,45	39,63
1993	95,25	18,15	19,80	18,13	0,08	46,18
1994	95,41	20,01	21,50	18,09	0,60	39,22
1995	94,16	20,43	17,49	19,21	0,29	41,57
1996	93,56	18,13	16,01	17,55	0,69	42,94
1997	92,98	18,80	16,27	17,51	1,08	38,91
1998	92,92	19,19	16,95	18,06	0,90	38,33
1999	90,04	18,99	15,37	16,68	0,46	29,98
2000	89,49	18,73	13,61	16,64	0,68	24,94
2001	84,29	19,57	13,19	18,96	1,10	19,84
2002	85,74	18,26	12,11	17,62	1,21	26,25
2003	87,16	17,08	13,43	15,04	0,42	25,29
2004	86,03	18,96	14,66	16,22	0,50	30,73
2005	87,12	18,20	16,86	16,18	0,67	24,54
2006	86,75	17,49	18,05	15,59	1,26	25,25
2007	88,21	17,52	18,38	15,26	0,43	19,03
2008	84,27	15,91	16,80	17,74	0,57	17,35
2009	89,00	17,64	15,87	17,86	0,67	19,58

2010	84,72	16,12	16,60	18,62	0,92	26,38
2011	87,16	15,80	17,74	16,76	0,89	25,33
2012	82,57	15,56	16,16	19,97	0,57	27,23
2013	76,80	17,17	17,57	20,30	0,55	28,82
2014	72,58	16,57	16,49	22,19	1,28	20,89
2015	73,48	15,86	15,31	23,85	2,32	31,96
2016	79,71	17,05	16,08	24,67	3,09	32,89
2017	78,42	17,05	16,94	24,84	3,99	29,34
2018	81,57	17,30	17,89	25,78	4,83	32,08
2019	81,42	17,57	19,70	26,97	5,06	43,52
2020	83,17	19,88	21,15	28,24	6,02	41,85
2021	77,36	19,05	21,44	28,61	7,26	35,42
2022	87,68	17,92	22,04	30,15	8,43	41,97
2023	88,99	--	20,40	30,65	9,25	41,73

Source: OECD Data Explorer.

POLICY RECOMMENDATIONS FOR INCREASING ENERGY PRODUCTIVITY

Energy productivity is a key element of the OECD's green growth indicators. Within the scope of energy productivity, countries should increase their total energy supply, increase the share of energy obtained from renewable sources in the total energy supply, and turn to renewable sources instead of fossil resources in the electricity produced. In this context, countries should give importance to energy transition and accelerate the transition from fossil fuel sources to renewable energy sources. The main point to be considered in policies to increase energy productivity is not to ignore the differences between countries. Countries' energy supply and demand, energy infrastructure, technological development levels, and production capacities differ from each other. This difference should be considered in the policies created for energy productivity, and countries should create their own policies that are appropriate to their conditions (Grodzicki and Jankiewicz, 2024). In creating policies, cooperation should be exercised, and it should not be forgotten that different stakeholders must work in harmony toward a common goal. The process of increasing energy productivity and adapting to renewable energy requires the cooperation of different stakeholders, including policymakers, researchers, companies, and individuals. Each stakeholder plays its own roles and responsibilities. For example, policymakers should implement regulations that encourage energy productivity and take measures to identify and minimize barriers to the transition to renewable energy. Researchers should increase studies that reveal the relationship between energy productivity and climate crisis and environmental pollution should be increased. They should conduct studies to determine strategies that will increase energy productivity by helping increase their knowledge of the subject. Companies should plan and implement projects that will increase energy productivity and use renewable energy sources. They must innovate production technologies and develop systems that use cleanest energy sources at minimum amounts. Individuals should also turn to clean energy use and shape their expectations and demands in this direction (Ekechukwu and Simpa, 2024).

In increasing energy productivity, sectoral productivity improvements should be given importance. Because sectoral improvements also contribute to the improvement of overall

energy productivity. The productivity, technological advancement level, and energy intensity of each sector are different from each other. For this reason, the methods and policies to be applied to increase each sector's energy productivity also differ. Applying the same policies to every sector and expecting the same results from the implemented policies may not yield healthy results. Considering this, sectors should implement policies appropriate to their internal dynamics, and each sector should take steps to increase energy productivity (Sak and Guloglu, 2025). However, in order to take steps to increase energy productivity and transition to systems based on renewable energy, the amount of resources allocated to these areas must be increased. Establishing renewable energy facilities, converting existing production systems to renewable energy sources, and establishing the necessary infrastructure involves high costs. It is very difficult for each company to cover these costs using its own resources. Companies require external financing. Traditional financial models characterize renewable energy projects as risky, and financial institutions are reluctant to provide resources for these projects. At this point, the importance of sustainable finance is evident. Sustainable finance contributes to energy productivity by producing financial instruments to meet the needs of renewable energy projects and by implementing risk-sharing mechanisms (Onabowale, 2024). Therefore, to increase energy productivity, countries should try to accelerate the transition to sustainable finance and expand sustainable finance instruments. Thus, the necessary resources can be created for investments that consider energy productivity and environmental quality. In addition, it is important for governments to support companies through practices such as tax incentives and implement the appropriate legal framework for companies that want to switch to renewable energy. Public-private collaboration is necessary to increase energy productivity (Sampene, Li, & Wiredu, 2024).

While companies need to adapt their production processes to renewable energy to increase energy productivity, this process cannot be considered independently of personnel behavior. It is important to use energy at minimum levels to improve energy productivity. Personnel must be conscious of this issue, internalize efforts to increase energy productivity, and know energy saving techniques well. Companies should integrate energy productivity training into their workforce development processes. Training should be organized at certain periods on topics such as which techniques to apply and how to apply them to increase energy productivity, the importance of energy productivity, and the costs of low energy productivity (Suef and Dinariyana, 2024). The trainings organized should be disseminated to the public and sector employees. Energy productivity and clean energy policies are topics that everyone should be aware of. Increasing public awareness of these issues and making savings in energy use, as well as in energy production, will make it easier to achieve these goals. In order to implement all these applications, long-term planning should be conducted, clear goals should be set, and it should be decided which goal will be achieved and at what time. In addition, the implemented policies should comply with transparency and accountability criteria (Oduro, Simpa, & Ekechukwu, 2024).

CONCLUSION

In this study, the green growth performances of the BRICS-T countries were examined within the scope of energy productivity. Data covering the period 1990-2023 for countries were considered. Although many indicators can be examined regarding energy productivity, the indicators determined by the OECD are included in this study. Countries' energy intensity, energy productivity, total energy supply, renewable energy supply, and renewable electricity generation data were compared.

Brazil ranks first among the BRICS-T countries in terms of the share of renewable electricity generation in terms of total electricity generation. Brazil also has a successful outlook compared to the other five countries in terms of its share of renewable energy supply energy supply. In Brazil, the share of renewable energy in the total energy supply is generally above 40%. In other countries this rate is much lower. Energy intensity in Brazil has increased over time. Increasing energy intensity means that more energy is used to produce a unit of goods. This is an undesirable situation in terms of energy productivity. Brazil must take measures to reduce its energy intensity.

Russia is the country with the highest total energy supply value among the BRICS-T countries, after China. However, it is noteworthy that despite its success in energy supply, it has not been able to demonstrate the same success in terms of energy density. Among the six countries in question, Russia has the highest energy density. This is an indication that Russia is not using energy efficiently. The share of renewable energy supply in the total energy supply in Russia is quite low. In fact, Russia has the lowest rate among BRICS-T countries in terms of renewable energy supply. It is important for Russia to focus on increasing its renewable energy supply, increasing the amount of resources allocated to renewable energy investments, and switching to production technologies that will use energy more efficiently.

India has gradually increased its total energy supply over time. Considering the share of renewable energy in the total energy supply, India is the most successful country after Brazil. The share of renewable energy supply in India is generally above 20%. However, energy intensity in India has increased over time. Although India has the lowest energy intensity among the BRICS-T countries, the increasing trend in energy intensity is a negative situation in terms of energy productivity. The lower the energy density, the less energy is required to produce a unit of goods, and the energy is used more efficiently.

China is the leader among the BRICS-T countries in terms of the total energy supply. It has gradually increased its total energy supply over time. However, the share of renewable energy in total energy supply is on a decreasing trend. Energy intensity has increased gradually in China, as in other countries. China should increase its renewable energy supply and accelerate the transition from fossil fuels to renewable energy sources. It should also focus on reducing energy intensity and creating production systems that use energy more efficiently.

The share of renewable energy in the total energy supply in South Africa is quite low. The share of renewable electricity generation electricity generation has also tended to increase over time, although it is quite low compared to other countries. South Africa is a country with high energy intensity. Therefore, there is a need to take measures to use energy more efficiently. South Africa should prioritize increasing both its total energy supply and renewable energy supply within its total energy supply.

There has been a gradual increase in the total energy supply in Türkiye over time. It is observed that there is a need to increase the share of renewable energy in the total energy supply. Türkiye is the second country with the highest share of renewable electricity generation in total electricity generation after Brazil. The increase in energy intensity observed in other countries is also valid for Türkiye. Türkiye also needs to prioritize the use of energy more efficiently by reducing its energy intensity.

One of the main elements that draws attention to the energy productivity indicators in BRICS-T countries is the increasing trend in energy intensity. Countries should work to reduce their energy intensity. For this purpose, new technologies and production systems that can increase energy productivity are needed. Similarly, countries must accelerate their energy transformation processes. They should focus on increasing the share of renewable energy sources in energy supply and using renewable resources in the production of electrical energy, which is one of the basic elements of the economy. This requires long-term policies. Following the planning process, the correct direction of economic and human resources should be ensured. Increasing the energy productivity of countries will help them become economically stronger, improve their environmental quality, and achieve their green growth goals.

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