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A review of renewable energy investment in the BRICS countries: History, models, problems and solutions

Shihong Zeng[a,c,*], Yuchen Liu[b,c], Chao Liu[a,c,*], Xin Nan[a,c,*]

[a] College of Economics & Management, Beijing University of Technology, Beijing 100124, China
[b] Beijing-Dublin International College, Beijing University of Technology, Beijing 100124, China
[c] Finance and Economics Development Research Center, College of Economics & Management, Beijing University of Technology, Beijing 100124, China

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ABSTRACT

This paper reviews the history of renewable energy development in the BRICS countries. The financing models for renewable energy development of BRICS countries include bank financing, institutional loans, industry funds, and international financing. This paper identified several problems with financing in BRICS countries, including a lack of financing channels, investment shortage for small and medium-sized enterprises and imperfect government policies. The solutions to these problems include expanded capital markets, the financing of leasing services, and build-operate-transfer and build-own-operate projects; further, a financial citizen participation model should be employed similar to that as Germany and European Union emissions trading system (EU ETS). A financial citizen participation model means that legal entities, private individuals, and agricultural enterprises invest in renewable energy infrastructure through equity. A regional reserve ratio monetary policy is suggested to allow regions to develop renewable energy.

1. Introduction

Fossil fuel energy is consumed by humans to sustain daily activities, but burning large amounts of fossil fuels leads to an increase of CO_2 in the atmosphere [1]. More than 30 billion tons of CO_2 are released due to fossil fuel burning each year, an amount that considerably exceeds the level that can be recycled by nature [2]. The residual CO_2 stays in the atmosphere for a relatively long time and results in global warming [3], which is the elevation of temperatures worldwide, especially in the two polar regions. From 1900–2015, the global average temperature rose by 1.02 °C [4]. In the Arctic region, the speed of the increase in average temperature is twice the speed elsewhere. This phenomenon is altering the environment, in part as ice melts in polar regions: the largest single block of ice in the Arctic, which had remained complete for thousands of years, recently broke into pieces [5]. The sea level is rising more rapidly, and the amount of precipitation is increasing. The slight rise in temperature has also had a huge impact on animals, for example, the number of Adélie penguins in Antarctica decreased by more than a half in the past 30 years. Many species are facing extinction due to global warming [6], which poses threats to the safety and health of humans. Natural catastrophes resulting from climate change may cause human injury and death [7].

These harmful effects will worsen if the temperature continues to rise. Reports suggest that if humans do nothing about CO_2 emissions, by 2100 there is a 50% possibility that the global average temperature will have risen by 4 °C [8].

Renewable energy is considered to be the most effective way to minimize CO_2 emissions. Reports suggest that burning coal emits 1.4–3.6 pounds of CO_2E/kWh. However, using renewable energy sources, such as wind, can produce as little as 0.02–0.04 pounds of CO_2E/kWh [9]. The difference is huge. Therefore, renewable energy sources need to be developed to replace the carbon-intensive energy sources in BRICS countries. For example, some achievements in this area have been attained in Germany. In 2014, 27.3% of German electricity generation utilized renewable energy. As a result, the greenhouse gas emissions in Germany dropped to their second-lowest level since 1990 thanks to the development of renewable energy. In the meantime, the economy of Germany grew by 1.4% [10]. The BRICS countries have abundant renewable energy resources. For instance, China has extensive wind resources in Inner Mongolia and major resources for biomass energy in rural areas [11]. India is a tropical country with an average annual temperature of between 25 °C and 27 °C; it receives 5000 trillion kW h equivalent in solar energy, a condition very suitable for the development of solar energy [12]. Water resources in Brazil are abundant for building hydroelectric power stations [13]. Russia both exports and consumes large amounts of fossil fuels every year but also

* Corresponding authors at: College of Economics & Management, Beijing University of Technology, Beijing 100124, China.
E-mail addresses: zengshihong@bjut.edu.cn (S. Zeng), lindaliu0225@yeah.net (Y. Liu), liuchao@bjut.edu.cn (C. Liu), 460182810@qq.com (X. Nan).

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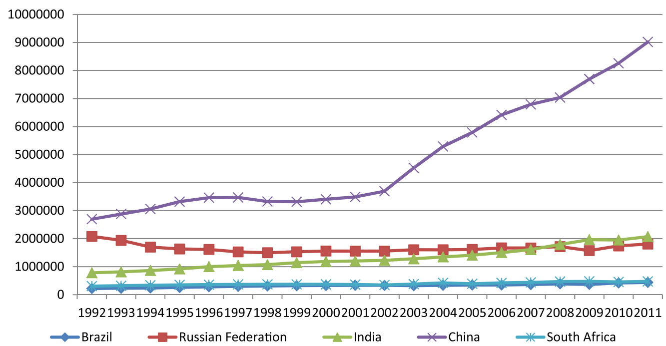

Fig. 1. CO_2 emissions (million kT) in BRICS countries.

possesses many renewable energy resources that present significant potential [14]. South Africa, in turn, has ideal solar energy resources [15].

Despite the ample variety of renewable energy resources in the BRICS countries, most of these resources are underdeveloped. To develop renewable energy, one major requirement is investment and financing. Therefore, it is important to study renewable energy investment and financing in the BRICS countries.

Although The theory of technological innovation systems [16,17] identifies many dimensions that can be applied to the development of renewable energy (RE), including knowledge creation and absorption and direction of search, the intermediary financial institutions and the capital markets are becoming more important [18–20].

The rest of this paper is organized as follows: Section 2 examines the CO_2-emitting context and the history of renewable energy industry development in BRICS countries. Section 3 analyzes financing models in different countries. Section 4 discusses current problems and some solutions. Section 5 concludes the paper.

2. Overview of CO2 emissions and renewable energy industry development in BRICS countries

To ensure data availability and consistency for the BRICS countries, data from 1992 to 2011 was selected for the analysis. From 1992–2011, the total CO_2 emissions in BRICS countries increased by approximately 170,000 kT. In 2011, the BRICS countries accounted for 40% of the world total CO_2 emissions. Of the world's five largest total CO_2 emitting countries, three are BRICS countries. China released the largest amount of CO_2 among the five countries, particularly in the last 10 years. The Russian Federation and India also produced a relatively large amount of CO_2, as shown in Fig. 1. Compared with other countries, China, India and the Russian Federation produce considerably higher amounts of CO_2. Although the figures for Brazil and South Africa are lower than those for the other three BRICS countries, they continued to rise after 1992. The CO_2 emissions per capita (metric tons) of the Russian Federation and South Africa are the highest of the five countries because they have a lower population than China and India, as shown in Fig. 2. Fig. 3 illustrates CO_2 emissions per

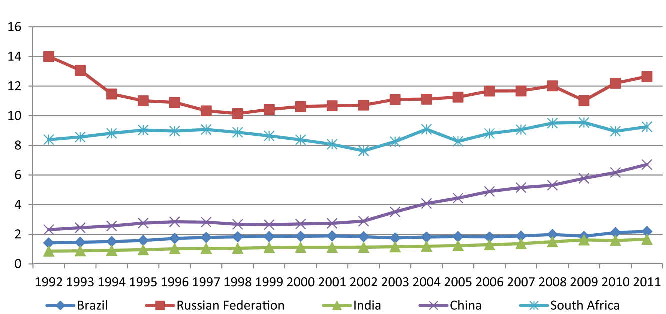

Fig. 2. CO_2 emissions (metric tons per capita) in BRICS countries.

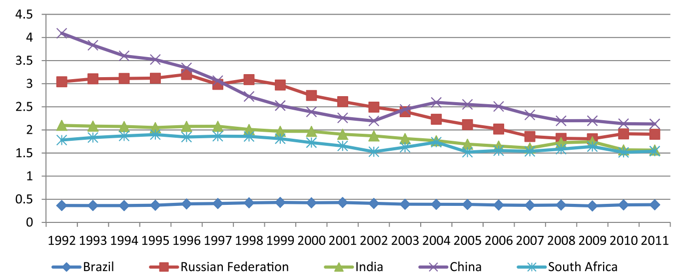

Fig. 3. CO_2 emissions (kg per 2005 US GDP) in BRICS countries.

GDP in the BRICS countries [21]. These data indicate that the BRICS countries contribute significantly to global CO_2 emissions. Thus, it is necessary and urgent to reduce the CO_2 emissions of the BRICS countries.

2.1. Brazil

Although the level of Brazil's total CO_2 emissions was relatively low in BRICS countries, the emission amount per GDP is the second highest. This warns Brazil that it needs to use more renewable energy instead of fossil energy in its development. Brazil possesses considerable renewable energy resources, especially hydropower, and its renewable energy exploitation and application are relatively mature in South America.

The Amazon provided Brazil with massive water resources. However, by 1910, Brazil already had 7.5 million kWh of available storage capacity in the city of Sao Paulo, and the storage capacity continued to rise from that point on [22]. In the 1970s, hydropower could supply 20% of the total energy consumption in Brazil, which was extremely high for renewable energy. Most of this power was generated in the southeast part of Brazil [23]. Meanwhile, wind energy was not exploited to generate electricity, and solar energy was only used to dry soybeans [24].

In the 1990s, Brazil's first anemograph and computer-controlled sensor for wind energy were installed. Thanks to the collected data, wind turbines were constructed, making a substantial contribution to the reduction of CO_2 emissions [25]. Hydropower also developed rapidly, but its achievements were at the cost of the environment. The construction of dams caused serious floods, and caused substantial harm to the forests of Brazil [26].

From 2001–2011, Brazil's total renewable energy consumption continued to rise at a moderate speed, reaching a peak of 463,272,000 MWh in 2011 [27]. By the end of 2010, 47.3% of the country's primary energy was renewable, far exceeding the world average of 13% [28]. However, the drought in Brazil starting in 2004 had a great impact on hydropower [29]. In 2014, the drought had reduced Brazil's hydro reservoirs by more than 60%. Fortunately, the government had progressed in other areas of clean energy. Power was supplied to the 2014 World Cup game from 6000 solar panels installed on the stadium, marking the first World Cup game successfully powered by solar energy. There is currently 11 MW of installed solar capacity in 2014 in Brazil, and the government plans to increase the number to 3500 MW by 2018 [30]. Although the share of total energy generation was small, wind energy in Brazil has also made impressive achievements in the past decade. In 2011, with 1000 MW of installed wind capacity, Brazil ranked first in South America [31]. Brazil has been very ambitious in the area of wind energy; with the help of increased funding and technology, wind energy is expected to provide 7% of the country's total electricity by 2020 [32].

2.2. Russian federation

Currently, Russia is the third largest CO_2 emitting country, just behind China and the US, and its emissions figure has been rising slowly in recent years [9]. Russia owns large amounts of fossil energy but has also continued to seek opportunities in the renewable energy area.

The Russian Federation was established in 1991 after the break-up of the Soviet Union. Due to the post-Soviet recession, infrastructure investment in Russia also dropped. This posed great problems for Russia's renewable energy development in the 1990s. The construction of dams and hydropower plants was cancelled, and oil and gas became the major energy sources in Russia [33]. Until 1994, there was no renewable energy consumption except hydropower. In 1994, the Kalmykia regional electric power utility recognized the importance of renewable energy and utilized domestic technology to build a 22 MW wind farm.

Barriers to development were inevitable. In the early 1990s, renewable energy research funding from the government decreased as renewable energy development was overlooked by the Russian government in favor of other industries. Subsidies were insufficient, so the public lacked incentives to invest in household solar products. There were other barriers in terms of transactions and markets, although joint ventures found methods to overcome some of the major barriers. In joint ventures, foreign corporations provided capital, business and marketing, while Russian corporations provided information by using personalized contact networks. Successful examples are the Windenergo joint venture and the SovluxUS-Russian joint venture in Moscow [34,35].

In the 21st century, Russia focused more attention to renewable energy development to reduce CO_2 emissions and protect the environment.

Russia and the EU began to work together to exploit the massive renewable energy resources in Russia's northwest [36]. Russia installed several wind generators in this area, which has abundant wind resources. For instance, in 2014, huge wind generators were built on the shores of Oktyabrsky, the far East region of Russia. By 2015, the wind turbines supplied 30% of the electricity needs in Oktyabrsky. Russia's solar energy also made significant achievements: the first solar farm in Batagai conserved major amounts of fossil energy.

By the end of 2015, Russian solar plants and wind generators were estimated to generate 60 MW and 1700 MW of capacity, respectively. However, these numbers are less impressive compared with the achievements in other countries such as the US and Germany [37]. Financial support for renewable energy in Russia was still inadequate, preventing the launch of many projects [36]. Thus, the development space for renewable energy in the Russian Federation continues to be very large.

2.3. India

The total CO_2 emissions level in India ranks No. 4 in the world and has risen rapidly since the 1990s [21]. It is urgent for India to develop renewable energy and reduce fossil fuel consumption.

As early as the 1990s, some minor hydroelectric stations started generating electricity in India. However, given the technology level of that time, the output of the stations was very low [38]. Since this time, hydropower has developed slowly but steadily. During the 1960s, India began its initial exploration into renewable energy. In the mid-1960s, the country constructed a conventional multi-vane windmill at the National Aeronautical Laboratory to exploit wind energy. Over the next ten years, other types of wind mills were erected. These early developments in wind energy were targeted for irrigation purposes. There was a national program of solar PV during the 1970s, and a solar thermal program in the 1980s [39]. Using these experiences as a foundation, India then applied solar energy to daily life. By 1995, the installation of 700 PV pumps, 26,000 PV domestic lighting units and other facilities using solar energy was completed. Meanwhile, wind energy also developed. Constructed wind farms recently started generating power [40]. The cumulative installed wind capacity in the country reached 576 MW, accounting for 30% of the addition to global capacity [39].

Currently, wind power has the largest accumulated installed capacity among various renewable energy types. It accounts for more than half of the total renewable energy capacity. Solar power is closing behind, having reached 8513.23 MW by the end of 30 September 2016 [41].

2.4. China

China's CO_2 emissions increased more than three-fold in the past decade, which contributed greatly to the global carbon emissions growth [21]. However, in 2014, China's emissions decreased by 0.7%, while energy consumption grew, an event that was unprecedented in recorded history [42]. In 2015, the consumption of non-fossil energy was 12% of the total, which was 0.8% higher than the percentage in 2014 [43]. These data show the great achievements made by China in renewable energy development.

The history of China's renewable energy development can be divided into four stages.

2.4.1. The first stage (1949–1979)

This stage is the earliest period of China's renewable energy development, which started from the establishment of the PRC. In this period, the concept of renewable energy had not yet formed systematically, and only a few programs were launched.

Hydropower in rural areas was developed, but the process was slow due to the shortage of capital, technology and management. The Gutian cascade hydropower project in Fujian Province started in 1952 and was completed in 1973: it took over 30 years to construct this hydropower station. During this period, there were no stations built on large rivers. Until the late 1970s, the total installed capacity of small hydropower stations did not even reach 7 million kW. The annual output capacity was 0.23 million kW [44,45]. A wind energy project was launched in Inner Mongolia in the late 1950s. In 1958, there were only 300 units of installed household wind generators [46]. Before 1980, the primary purpose for developing renewable energy was to provide people in rural areas with electricity [47].

As for solar energy and other sources of renewable energy, in the 1970s China began applying solar thermal energy [48]. In 1968, China constructed wave-powered ship models to explore wave energy. Subsequently, a wave-powered turbine was built, but a failed test on the East China Sea in 1972 proved the turbine unsuccessful [49].

2.4.2. The second stage (1980–1989)

China's Sixth Five-Year Plan proposed the goal of energy conservation. The related policies encouraged the Chinese people to stop depleting fossil energy, and substantial investments were made to achieve this goal [50]. Thus, from 1980 on, China's renewable energy use began to develop rapidly.

In the 1980s, China constructed five large and medium-sized cascade hydropower stations on the Yellow River, China's second longest river [45]. Wind energy projects were also considered important, and developed rapidly: by the end of 1990, 86,000 units of household wind generators generated a total capacity of 9100 kW, supplying increasing numbers of people in rural areas with electricity. Grid-connected wind farms did not appear until 1986 and started to work in 1989 [51]. The first wind farm was built in Rongcheng County, Shandong Province and soon after, the second wind farm was constructed in Pingtan County, Fujian Province. From that point on, wind farms were constructed all over China [52]: by the end of 1990, the number of wind farms was 5 units and the total capacity was 500 kW [51]. In the late 1980s, China produced flat plate solar water heaters using foreign technology. However, because of cost and compatibility issues, their development was very slow [48].

2.4.3. The third stage (1990–1999)

In this decade, sustainable development was emphasized and considered to be a primary component of China's modernization process.

Additional small hydropower stations were built, which brought more benefits to local residents. At the end of the decade, the total installed capacity reached 23,500 MW [20]. The development of wind energy in Inner Mongolia experienced a revolution: prior to 1997, household generators accounted for the major part of the accumulated installed capacity, whereas after 1997, wind farms replaced the role of household generators and became the most important provider. In 1997, the capacity of wind farms increased to almost 40,000 kW, which was twice the capacity of household generators [46]. This represented a new era for wind farms in China. By the end of 1999, thanks to wind energy achievements, China had made significant progress in balancing its power demand and supply. However, power shortage problems in rural areas remained [47].

2.4.4. The fourth stage (2000–2015)

Entering the 21st century, China listed specific goals in different fields of sustainable development. With the deterioration of the environment, China gradually recognized the significance of renewable energy.

Installed renewable energy generation capacity increased considerably, especially from 2005 on. The figure rose from approximately 120,000 MW to approximately 375,000 MW between 2005 and 2013. During this period, hydropower generated the greatest portion of the total capacity. Moreover, China's small hydro capacity is now the world's largest. It is also worth noting that wind power has been assuming a larger share of the total capacity in recent years. From 2008–2013, the total generation capacity in China experienced six-fold growth, reaching 91,400 MW [53]. Wind power development is an example of energy strategies and green development in China [54].

Solar technology also took a big step forward. China produced only 6.1 million square meters of solar water heaters in 2000, but the number had soared to 42 million by 2009 [48]. Currently, China owns the largest market share for solar water heating technology in the world [55]. Until 2014, the total installed capacity of solar photovoltaic in China was 28,050 MW; 83.35% of it was stationary PV and 16.65% was distributed PV [56,57].

There were also discoveries and accomplishments in other areas of renewable energy. In China, tidal energy was approximately 1.9 billion kW, and 20.98 million kW was exploitable. Currently, China has two operating tidal power stations, both of which are in Zhejiang Province. Although the research and operating costs are high, the two stations generated a total capacity of 4150 kW. Among all potential ocean-related renewable energy sources such as wave energy and offshore wind energy, tidal energy exploitation technology is the most mature [58].

Although the renewable energy achievements in China are remarkable, its level of CO_2 emissions is still the highest in the world. China needs to put more effort into renewable energy to reduce CO_2 emissions.

2.5. South Africa

Of the five BRICS countries, the CO_2 emissions per capita in South Africa were just behind Russia and much higher than those of the other three countries. The history of renewable energy in South Africa is relatively brief. This country was isolated internationally before 1994, and survival was its biggest problem. Information concerning energy was restricted by the government, which had a major impact on the development of renewable energy [59].

In the late 1990s, solar energy made some initial progress, and solar energy application tests were performed for the public [60,61]. However, it was not until 2011 that PV was installed in South Africa; subsequently, the number of PV installations soared. By 2014, total installations accounted for 992 MW [62]. South Africa became the first country with installed PV capacity approaching 1000 MW [63]. There was no wind power capacity installed in Africa prior to 1997 [64], and little was achieved in this area before 2014. However, the accumulated wind energy installation increased by 634 MW and 544 MW in 2014 and 2015, respectively [65]. The South African wind energy program contributed much to this success. This program was launched in 2008 and lasted for five years. Large-scale wind generators were constructed in the Darling Wind Farm in 2008 [66,67], and subsequently, more wind farms were erected in both eastern and western areas of South Africa [68,69]. South Africa's renewable energy is not as mature as that of the other four BRICS countries, so joining the BRICS has presented a good opportunity for South Africa to collaborate to develop its renewable energy.

3. Quantitative analysis

3.1. The impact of the proportion of renewable power on carbon emission intensity

3.1.1. Data

Table 1 illustrates CO_2 emissions by GDP in the BRICS countries. The BRICS countries are ranked China, Russian Federation, India, South Africa, Brazil for CO_2 emissions by GDP.

Table 2 illustrates the ratio of electricity production from renewable sources excluding hydroelectric (% of total) in the BRICS countries. In Brazil, the ratio of electricity production from renewable sources excluding hydroelectric (% of total) is the largest among BRICS countries.

We will analyze the impact of the proportion of renewable power on carbon emission intensity employing panel data.

3.1.2. Panel unit root test

In general, a regression analysis with non-stationary data may create a spurious regression problem; thus a data stationarity test is required before the regression analysis.

A panel data stationarity test can be conducted using a variety of methods. The unit root methods can be divided into homogeneous unit root tests (including the LLC test) and heterogeneous unit root tests (the Fisher-ADF test) according to whether all section sequences have

Table 1
CO_2 emissions by GDP in the BRICS countries.

Year	Brazil	Russian Federation	India	China	South Africa
1992	0.36	3.04	2.10	4.09	1.78
1993	0.36	3.11	2.08	3.83	1.84
1994	0.36	3.11	2.07	3.60	1.87
1995	0.37	3.12	2.05	3.52	1.90
1996	0.40	3.20	2.08	3.34	1.85
1997	0.41	2.99	2.08	3.07	1.86
1998	0.42	3.09	2.01	2.72	1.86
1999	0.43	2.97	1.97	2.53	1.81
2000	0.42	2.75	1.97	2.39	1.73
2001	0.43	2.61	1.91	2.26	1.65
2002	0.41	2.49	1.87	2.20	1.53
2003	0.39	2.39	1.81	2.44	1.63
2004	0.39	2.23	1.77	2.60	1.73
2005	0.39	2.11	1.69	2.55	1.52
2006	0.37	2.02	1.65	2.51	1.55
2007	0.37	1.86	1.61	2.33	1.54
2008	0.38	1.82	1.72	2.20	1.59
2009	0.36	1.81	1.74	2.20	1.64
2010	0.38	1.92	1.57	2.14	1.52
2011	0.38	1.91	1.56	2.13	1.54
average	0.39	2.53	1.87	2.73	1.70

The data source: http://data.worldbank.org/indicator/EN.ATM.CO2E.KD.GD.

Table 2
The ratio of electricity production from renewable sources excluding hydroelectric (% of total).

Year	Brazil	Russian Federation	India	China	South Africa
1992	2.03	0.01	0.03	0.02	0.00
1993	1.97	0.01	0.03	0.02	0.00
1994	2.07	0.01	0.05	0.05	0.00
1995	2.03	0.01	0.13	0.31	0.00
1996	2.32	0.01	0.21	0.15	0.03
1997	2.40	0.01	0.22	0.26	0.07
1998	2.33	0.01	0.22	0.25	0.11
1999	2.50	0.01	0.44	0.24	0.10
2000	2.25	0.01	0.52	0.23	0.15
2001	2.74	0.01	0.68	0.23	0.15
2002	2.97	0.02	0.85	0.21	0.12
2003	3.28	0.04	1.05	0.19	0.11
2004	3.24	0.05	1.25	0.18	0.11
2005	3.40	0.05	1.54	0.30	0.11
2006	3.57	0.05	1.98	0.39	0.11
2007	4.19	0.05	2.34	0.48	0.11
2008	4.46	0.05	2.74	0.86	0.12
2009	5.11	0.05	3.33	1.28	0.13
2010	6.53	0.05	3.48	1.67	0.12
2011	6.57	0.05	3.95	2.22	0.13
average	3.30	0.03	1.25	0.48	0.09

The data source: http://data.worldbank.org/indicator/EG.ELC.HYRO.ZS.

the same unit root process. This article uses the LLC test and the Fisher-ADF test. For both tests, the null hypothesis is that each section sequence contains a unit root. For the LLC test, the alternative hypothesis is that each section sequence is stationary, while the alternative hypothesis of the Fisher-ADF test is that some section sequences contain no unit root. The test results are shown in Table 3. The variable R represents the electricity production ratio from renewable sources excluding hydroelectric (% of total). The variable E represents carbon emission intensity.

The p values for R are greater than 0.05 for the LLC test and Fisher-ADF test, as shown in Table 3. The null hypothesis cannot be rejected: R is a non-stationary sequence.

The p values for DR are less than 0.05 in the LLC test and Fisher-ADF test, as shown in Table 3. The null hypothesis can be rejected: DR is a stationary sequence.

The p values for E are less than 0.05 in the LLC test and Fisher-ADF test, as shown in Table 3. The null hypothesis can be rejected: E is a stationary sequence.

Considering carbon intensity in the sequence, according to the results of the LLC test and Fisher-ADF test, the corresponding p values were significantly less than 0.05, and the null hypothesis that E is a stationary series can be rejected. Because E and R are not integrated on the same order, the difference in R is analyzed.

3.1.3. The panel data regression model analysis

This model uses the variable intercept model based on the F test. The individual fixed effects model is selected for this paper to analyze individual countries and between countries.

Consequently, an individual variable intercept fixed effect model is established.

The model form is as follows:

$$E_{it} = \alpha + \alpha_i^* + \beta \times DR_{it} + u_{it} i = 1, 2, \ldots, 5, t = 1, 2, \ldots, T$$

where

E_{it} represents the carbon emission intensity in year t for country i. DR_{it} represents the net growth in year t of the ratio of electricity production from renewable sources excluding hydroelectric (% of total) for country i.

α represents the average carbon emission intensity of the BRICS countries.

α_i^* represents the deviation in carbon emission intensity of country i from the average carbon emission intensity of the BRICS countries. α_i^* shows the structure of the carbon intensity differences between countries.

u_{it} represents the random error term and satisfies the hypothesis that the average is zero. The variance is σ_u^2.

The cross-sectional model may contain potential heteroscedasticity and the contemporaneous correlation problem. Thus, the feasible generalized least squares (FGLS) estimation method is employed. The estimation results are as follows:

$$\hat{E}_{it} = 1.8387 + \hat{\alpha}_i^* - 0.1654 \times DR_{it}$$

$$t = (152.7277) \ (-3.6796)$$

R^2=0.93 F-statistic=252.2231.

The estimation results of α_i^* are shown in Table 4.

α and DR pass the t-test at a 5% significance level. The goodness of fit of the model R^2 is 0.93. The F test valuation is 252.2213. Therefore, the model fit results are good.

The impact of the net growth in the five BRICS countries' electricity production rate from renewable sources excluding hydroelectric (% of total) on carbon emission intensity is negative, as seen in Table 4.

The carbon emission intensity decreases 0.16 units when the net growth in the electricity production rate from renewable sources excluding hydroelectric (% of total) increases 1 unit.

The lower carbon intensity is, the greater the net growth in the electricity production rate from renewable sources excluding hydroelectric (% of total). Significant differences exist in carbon emission intensity from 1992 to 2011. China's carbon emission intensity is the highest, followed by Russia, India, and South Africa; the lowest carbon intensity is in Brazil.

3.2. Renewable energy investment trends for different development phases

Venture capital (VC) funds, government research and development (R & D) funds, and corporate research development and demonstration (RD & D) funds play an important role in renewable energy development.

The trends in VC, R & D, and RD & D funds are shown in Table 5 and Fig. 4, considering the technology development phase in renewable

Table 3
Panel unit root test.

variable	R		DR		E	
Test method	LLC t value 2.39914	Fisher-ADF z value 2.22545	LLC t value −4.84274	Fisher-ADF z value 31.0622	LLC t value −3.18841	Fisher-ADF z value 19.6123
p value	�−0.9918�	�0.9943�	(0.0000)	(0.0006)	(0.0007)	(0.0331)
Test type	(c,k,1)	(c,k,1)	(c,k,2)	�c,k,2�	�c,k,3�	�c,k,3�
Results	non-stationary	stationary	stationary	stationary	stationary	stationary

Note: All tests are at a 5% significance level; c, k, t in parentheses, respectively, represent the constant, trend term and lag order number; the lag order number is determined according to the SIC criterion.

Table 4
The estimation results for α_i^*.

Country	Estimate value
Brazil�BRA�	−1.4078
Russian Federation (RUS)	0.6627
India (IND)	0.0492
China (CHN)	0.8417
South Africa (ZAF)	−0.1457

Table 5
The trends in VC, government R & D, and corporate RD & D funds in the technology development phase.

Year	Venture capital ($bn)	Government R & D ($bn)	Corporate RD & D ($bn)
2004	0.4	1.9	3.2
2005	0.6	2	2.9
2006	1.2	2.2	3.1
2007	2.1	2.7	3.5
2008	3.2	2.8	4
2009	1.6	5.3	4.1
2010	2.5	4.7	4.2
2011	2.5	4.6	5.1
2012	2.4	4.5	5
2013	0.7	4.9	6.6
2014	1	5.1	6.6
average	1.7	3.7	4.4

Data source: [70].

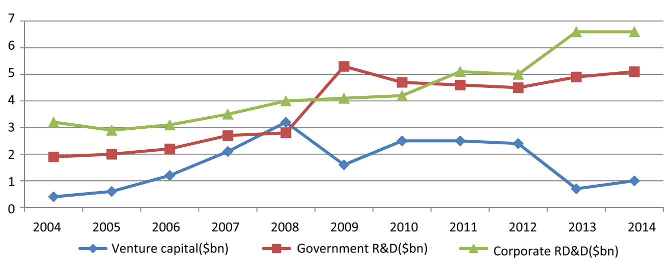

Fig. 4. The trend in VC, government R & D, and corporate RD & D funds for the technology development phase.

energy investment [70]. The average corporate RD & D fund is greater than the average government R & D fund, and the average government R & D fund is greater than the average venture capital from 2004 to 2014 considering the technology development phase in renewable energy investment.

The trend in private equity expansion capital (PEEC) for public markets is shown in Table 6 and Fig. 5, considering the equipment manufacturing phase in renewable energy investment [70]. The

Table 6
The trend in PEEC in public markets for the equipment manufacturing phase.

Year	Private equity expansion capital ($bn)	Public markets ($bn)
2004	0.3	0.3
2005	1	3.7
2006	3	9.1
2007	3.6	20.7
2008	6.8	10.9
2009	2.9	13.1
2010	3.1	11.4
2011	2.5	10.1
2012	1.7	3.9
2013	1.4	10.5
2014	1.7	15.1
average	2.5	9.9

Data source: [70].

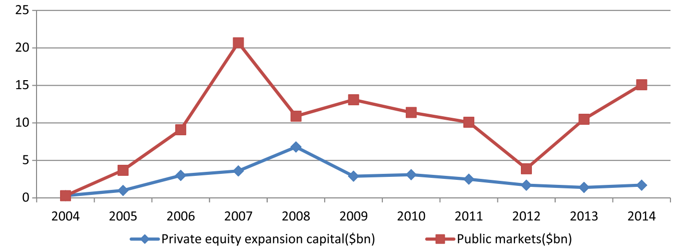

Fig. 5. The trend in PEEC in public markets for the equipment manufacturing phase.

Table 7
The trend in PE buyouts, PMIE, corporate M & A, PA & RF in the M & A transactions phase.

Year	PE buyouts ($bn)	PMIE ($bn)	Corporate M & A ($bn)	PA & RF ($bn)
2004	0.8	0.4	2.4	5.3
2005	3.7	2.4	7.6	12.5
2006	1.8	2.7	12.3	19.1
2007	3.6	4	20.3	30.6
2008	5.4	1	17.6	35.4
2009	2.2	2.5	21.8	37.8
2010	2	4.9	19.4	32.1
2011	3.1	0.2	30.1	40.1
2012	3.3	0.4	10.1	53.8
2013	0.6	1.8	15.2	49.3
2014	2.5	1.9	9.8	54.5
average	2.6	2	15	33.7

Data source: [70].

average public markets fund is greater than the average private equity expansion capital from 2004 to 2014 considering the equipment manufacturing phase in renewable energy investment.

The trends in private equity (PE) buyouts, public market investor exits (PMIE), corporate mergers and acquisitions (M & A), are project acquisition & refinancing (PA & RF) are shown in Table 7 and Fig. 6, considering the M & A transaction phase in renewable energy investment [70]. The average project acquisition & refinancing fund is greater than the average corporate mergers and acquisitions fund. The average corporate mergers and acquisitions fund is greater than the average

the average private equity (PE) buyouts fund. The average private equity (PE) buyouts fund is greater than the average public market investor exits fund.

The trend in new investment by sector is shown in Table 8 and Fig. 7, considering renewable energy investment. The sector includes wind energy, solar energy, biofuels energy, biomass energy & w-t-e(waste to energy), small hydro energy, geothermal energy, and marine energy. The wind and solar sector are the most important [70]. The order of the average new investment amount by sector is solar energy, wind energy, biofuels energy, biomass & w-t-e(waste to energy) energy, small hydro energy, geothermal energy, marine energy.

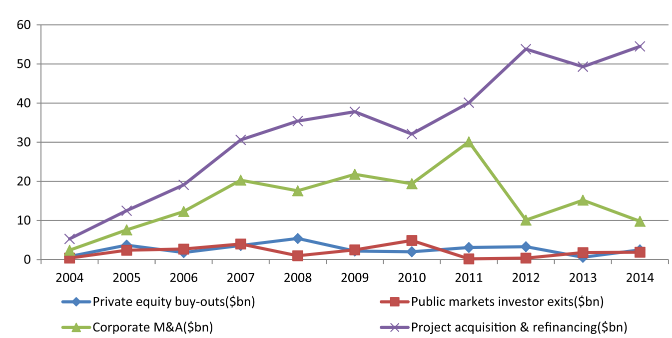

Fig. 6. The trend in PE buyouts, PMIE, corporate M & A, PA & RF in the M & A transactions phase.

Table 8
The trend of new investment by sector.

Year	Wind ($bn)	Solar ($bn)	Biofuels ($bn)	Biomass & w-t-e[a] ($bn)	Small hydro ($bn)	Geothermal ($bn)	Marine ($bn)
2005	17.9	12	3.9	7.4	2.6	1.2	0
2006	29.1	16.3	9.6	9.6	7.2	1	0.1
2007	39.6	22.1	28.4	12.1	7.6	1.5	0.9
2008	61.6	38	28.7	15.8	7.1	2	0.8
2009	75.2	60.8	19.2	16.9	7.8	1.7	0.2
2010	81.2	63.7	10.2	13.9	6.3	2.9	0.3
2011	98.9	103.3	10.1	16	5.7	3	0.3
2012	84.2	155.7	10.4	17.4	7.2	3.7	0.3
2013	84.1	144.3	7	12.4	6.4	1.8	0.3
2014	89.3	119.8	5.5	9.3	5.5	2.2	0.2
average	66.11	73.6	13.3	13.08	6.34	2.1	0.34

The data source: [70].
[a] Waste to energy.

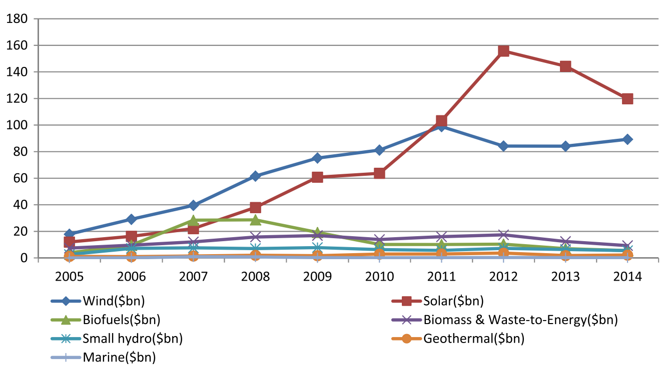

Fig. 7. The trend of new investment by sector.

The trend in new investment by geography is shown in Table 9 and Fig. 8, considering renewable energy investment. There is greater new investment in China than in Brazil, India, the Middle East or South Africa [70]. The order of the average new investment amount by geography is Europe, China, United States, Antarctic and Southern Ocean Coalition (excl. China & India), Brazil,

Americas (excl. US & Brazil), India, Middle East & Africa.

The trend of new investment by projects is shown in Table 10 and Fig. 9, considering renewable energy investment. Asset finance represents bank loans; small distributed capacity represents small-scale financing. The bank loan average value is the greatest among bank loans, re-invested equity, small distributed capacity, Government R & D, corporate RD & D, and small projects [70].

4. Renewable energy financing model

In terms of total capacity for renewable energy generation (not including hydropower), two BRICS countries (India and China) were among the top five worldwide as of the end of 2014. This marked a breakthrough in the renewable energy market for BRICS countries [71].

The Government of China extended US$36 billion in loan guarantees to renewable energy companies in 2010. China Longyuan Power Group raised US$279 million with loans from three banks in 2013 [72]. Starting in 2010, the total investment amount in India started to soar, reaching 12 billion dollars in 2011, which is double the amount for 2009 [73].

Different finance structures and arrangements play an important role in developing renewable energy. Bank financing and institutional loans, industry funds, international financing and other financing models work together for renewable energy development.

The bank financing and institutional loans model captures those enterprises that borrow money from commercial banks and non-bank financial institutions, which are often a country's financial market. The capital of commercial banks can be used to provide long-term loans and short-term loans to companies.

Industrial investment funds are generally for unlisted enterprises with high growth potential; these funds make equity or quasi-equity investments and participate in the management of the target enterprise. An industrial investment fund achieves capital appreciation through equity transfer. These funds can be divided into types such as seed industry funds or early funds, growth funds, or restructuring funds according to the different stages of the target enterprise. An industry fund involves multiple parties, including fund shareholders, fund managers, fund custodians and accountants, lawyers and other intermediary service agencies. The fund manager is responsible for operating the specific investment fund and for the daily management of the industrial investment funds. The difference between an industrial investment fund and the traditional method of creditor rights investment is that an industrial investment fund is not operated for current profit and loss but for the long-term development prospects and asset appreciation. This allows the fund to capture the high returns on capital by the listed or sold.

International financing occurs when an enterprise raises the liquidity, including the mid-term and long-term funds, needed for enterprise development from the international financial market. The goal of the enterprise is to enter a favorable market, expand the

Table 9
The trend in new investment by geography.

Year	US[a] ($bn)	**Brazil** ($bn)	AMER[b] ($bn)	Europe ($bn)	**MEA**[c] **($bn)**	**China** ($bn)	**India** ($bn)	ASOC[d] ($bn)
2005	5.4	**0.8**	1.7	23.6	**0.6**	**3**	**2.7**	7.2
2006	11.6	**3.1**	3.3	33.6	**0.8**	**8.2**	**3.1**	9.2
2007	29.1	**5.2**	3.9	46.7	**1.1**	**11.1**	**4.9**	10
2008	33	**11.8**	5	66.4	**2.4**	**16.6**	**6.3**	12.5
2009	35.1	**12.1**	5.8	81.6	**2.3**	**25.7**	**5.6**	13.6
2010	24.3	**7.9**	5.8	81.2	**1.7**	**39.5**	**4.3**	13.7
2011	35.1	**7.7**	12.2	111.1	**4.2**	**38.7**	**9**	19.3
2012	50	**10.1**	9.2	120.7	**2.9**	**49.1**	**12.7**	24.1
2013	38.2	**7.2**	10.2	89.6	**10.4**	**62.8**	**7.4**	30.5
2014	36	**3.9**	12.2	57.3	**8.7**	**62.6**	**6.4**	44.7
average	29.8	**7.0**	6.9	71.2	**3.5**	**31.7**	**6.2**	18.5

Data source: [70].
[a] United States,
[b] Americas (excl. US & Brazil),
[c] Middle East & Africa,
[d] Antarctic and Southern Ocean Coalition (excl. China & India).

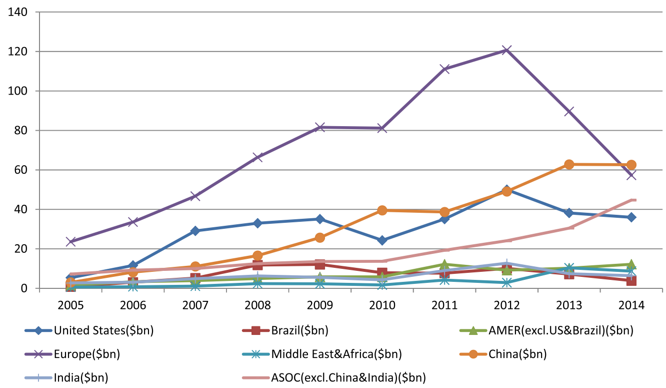

Fig. 8. The trend in new investment by geography.

Table 10
The trend in new investment by project.

Year	Asset finance �$bn�	RIE[a]�$bn�	SDC[b]�$bn�	G R & D,C RD & D, SP[c]�$bn�
2004	30.4	0	8.6	12.7
2005	52.5	0.2	10.3	15.3
2006	84.7	0.7	9.5	14.8
2007	110.4	3.1	14.1	20.2
2008	135.4	3.7	22.3	29.1
2009	120	1.9	33.4	42.6
2010	154.6	5.6	62.2	71.2
2011	181.2	3.3	76.1	85.9
2012	163.2	2.9	78.8	88.3
2013	154.6	1.9	54.9	66.4
2014	170.7	3.6	73.5	85.2
average	123.4	2.5	40.3	48.3

Data source: [70].
[a] RIE represents re-invested equity;
[b] SDC represents small distributed capacity;
[c] G R & D, C RD & D, SP represent Government R & D, corporate RD & D, and small projects.

availability of enterprise development funds, and reduce the cost of capital. International financing includes international bond financing, international stock financing, overseas investment fund financing, foreign government and other financial organization loans.

Other financing models include build, operate and transfer (BOT), VC, and PE.

The financing instruments for each model are shown in Table 11.

4.1. Overview of the bank financing and institutional loans model

4.1.1. Brazil

Similar to other BRICS countries, banks play an important role in renewable energy investing in Brazil: the National Development Bank is responsible for providing most new energy funds. The bank is state-owned and offers loan to manufacturing corporations at an interest rate of 6.4%, which is much lower than Brazil's annual base interest rate.

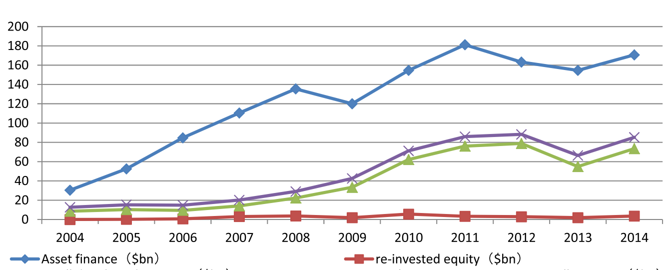

Fig. 9. The trend in new investment by project.

However, borrowers must satisfy strict requirements and need to repay loans within 20 years. The majority of wind energy investments are made by the National Development Bank [74,75], and the bank also provides loans to solar energy projects to help meet national goals.

4.1.2. Russia

Banks have provided loans to renewable energy developers in Russia. The World Bank group supports the Russia Renewable Energy Program (RREP), and these loans can stimulate private sector investment. This type of bank and private sector investment is projected to increase renewable electricity generation to 4.5% by 2020 [76,77].

4.1.3. India

Banks and agencies provide low-interest rate loans to renewable energy developers in India. There are approximately 15 commercial banks active in the area of renewable energy loans [74]. In 2008, the investment from local commercial banks reached 226 million dollars. The India Renewable Energy Development Agency is the major provider of loans in this area and offers low-interest rate loans to wind farms and small hydro projects [78].

4.1.4. China

Bank loans are the major funding resource for renewable energy in China. Domestic banks are divided into two types: policy banks and commercial banks. Policy banks, such as the China Development Bank, receive instruction from the government. For example, based on the government-issued policy, policy banks would offer loans with low-interest rates to renewable energy-related industries. Unlike policy banks, commercial banks tend to seek profitable projects. For example, in the 2000s, many commercial banks invested in photovoltaic manufacturing due to the high returns.

Wind energy has been developing rapidly in China, and bank financing has made a major contribution to this development; approximately 80% of these project funds come from bank loans. The proportion of centralized photovoltaic project funds from banks is also 80% [79]. In the small hydropower area, banks play an important role as well. Following preferable policies and low-interest rates from policy banks, commercial bank loans are also a major funding resource for small hydropower corporate financing and project financing [44]. Bank financing for funding renewable energy in China is relatively mature.

4.1.5. South Africa

Most renewable energy project funds in South Africa come from bank and institutional loans; the proportion ranges from 70% to 80%. Since the South Africa government launched the Renewable Energy Independent Power Producers' Program in 2011, it has received many of these loans. In this program, several banks are chosen by the developer to provide loans for the project. Four important banks in South Africa are active and have provided significant funding for this program: Standard Bank, NedBank, ABSA Capital and Rand Merchant Bank. Institutions such as South Africa's Industrial Development Corporation have provided loans as well [80,81].

4.2. Overview of the industry funds model

4.2.1. Brazil

To develop sustainable energy, the Brazilian government allocated substantial funds to certain area such as the Climate Fund. From 2015–2018, the government plans to invest up to 540 billion dollars to generate electricity, with a primary focus on renewable energy projects. Some of these funds come from private investors and some from state-owned enterprises. Furthermore, by the end of 2014, approximately 0.04 billion dollars was collected through VC and PE. In addition, 0.2 billion dollars for wind energy was raised from public markets in Brazil [82,83].

Table 11
The financing instruments for each model.

Model	Bank financing and institutional loans model	Industrial investment fund model	International financing models	Other financing models
Financing instruments	Long-term loans	Government research development (R & D) fund	International syndicated loans	Venture capital (VC)
	Short-term loans	Corporate research development and demonstration (RD & D) fund	International public markets, for example, New York stock market	Private equity expansion capital (PEEC)
	Asset finance	Seed fund	Project acquisition & refinancing (PA & RF)	Build, own and operate (BOO)
	Small distributed capacity	Re-invested equity	Corporate mergers and acquisitions (M & A)	Operate and transfer (BOT)

4.2.2. Russia

Russia claims that its total investment in renewable energy will reach 53 billion dollars by 2035. Small and medium-sized corporations have become more important in this sector. Renewable energy investment should accelerate faster than fossil fuel investment [84]. The Russian government provided 3 billion rubles in funds (0.423 billion dollars) to renewable energy-related areas [85]. In 2013, the government launched incentive policies in the electricity wholesale market to support renewable energy products, with satisfying results. This mechanism increased the profits of investments in the renewable energy area [86]. The government also encourages investors to invest in new energy projects [87].

4.2.3. India

The renewable energy industry in India receives subsidies from the Ministry of New and Renewable Energy Sources [78].

The Indian government has launched an US$8b grid upgrade program to resolve a weak infrastructure problem that has hindered renewable energy development [75].

The Indian government also provides direct funds to renewable energy projects. For instance, in 2011, the government allocated 189 million dollars in funds to the Jawaharlal Nehru National Solar Mission [88]. From 2011–2012, to boost the development of solar energy, the government invested 38.31 million dollars in related areas [89]. Government funds play a significant role in renewable energy investment.

India encourages private investors to invest in renewable energy. Policies provide incentives such as tax holidays and accelerated depreciation [90].

4.2.4. China

Government special funds are the most important funding resource type in the renewable energy industry. The funding process is implemented by various government departments. For instance, the Ministry of Water Resources is responsible for financing small hydropower development [78]. In 2006, the central government introduced a specific policy to regulate special funds for renewable energy. The policy gave the renewable energy industry priority in receiving government subsidies. In China, there are three categories of renewable energy subsidies. The first category is an investment subsidy, which is targeted at the investors in the program. For example, the "Song Dian Dao Xiang" program received over 4 billion RMB of government funding. The program successfully resolved electricity problems for thousands of people by using renewable energy. The second type is a product subsidy, but its application is limited. The third type offers subsidies to consumers. In rural areas, such as Xinjiang and Qinghai, the government subsidizes people if they purchase small photovoltaic or wind energy systems to generate electricity. This method encouraged people to utilize renewable energy [91].

The capital market is also now available for financing renewable energy in China, although its involvement is relatively new compared to other financing models. Some of the state-owned renewable energy enterprises are listed enterprises and are able to raise money from the public on the stock exchanges. As of June 2012, a total amount of 32.77 billion RMB has been raised in China's domestic stock market. For example, since China Longyuan Power was listed in Hong Kong in 2009, it has raised more than 17.7 billion RMB. Longyuan uses these funds for various purposes, including constructing renewable energy equipment and paying back bank loans. In addition to stock markets, state-owned renewable energy enterprises started to issue bonds in 2010, and this financing method also allowed them to obtain a considerable amount of funds [79]. Furthermore, private investments such as VC and PE are also becoming more popular in the renewable energy market. China became the third highest recipient country for VC in 2010 [92].

4.2.5. South Africa

In South Africa's Independent Power Producers' Programs, equity financing comprises 20–30% of the total. For example, South Africa's Industrial Development Corporation finances renewable energy projects by buying community trust shares. The government also provide funds through state-owned enterprises such as the Public Investment Corporation [80,93].

4.3. Overview of international financing

4.3.1. Brazil

Brazil uses foreign bank funds to support domestic renewable energy development. Japanese banks together with the Brazil National Development Bank raised 100 million dollars to protect the environment by exploiting renewable sources [81]. Joint ventures are common in Brazil.

Eduardo Campos signed a memorandum of understanding with the French company Eolice for the manufacture of wind turbine blades in Suape Industrial Complex, which would generate 1500 direct jobs with an investment of 100 million reais (approximately 26.45 US dollars). They plan to collaborate to discover further profits in the renewable energy area [74].

4.3.2. Russia

The European Bank for Reconstruction and Development invested 1197 million Euros in the Russian renewable energy industry, which grew to 25 projects related to sustainable energy production. Specifically, the bank offers loans mainly to small and medium-sized projects [94]. The Russian government and Europe together implemented the "joint projects with third countries" project. This project aimed to exploit Russian renewable energy to generate electricity and deliver it to Europe [87].

4.3.3. India

The World Bank and the Global Environment Facility started to finance Indian renewable energy projects in 1992. The first project received a 190 million dollar loan and a 26 million dollar donation. Four years later, the Global Environment Facility provided another 49 million dollars for India to develop a solar thermal power plant. By the end of 2014, the World Bank and the International Finance Corporation had invested 2 billion dollars [90,95].

International joint ventures exist in India. Policy states that joint ventures are not limited to the manufacturing area: they have the right to run their own renewable energy power generation projects [90]. India is an important country in China's One Belt One Road project, so many Chinese corporations are seeking opportunities to invest in the Indian renewable energy industry.

4.3.4. China

International financing continues to improve China's renewable energy development, and international financial institutions have invested substantial funds. For instance, Suntech received a $100 million loan in 2009 from the International Finance Corp [96].

Joint ventures and bilateral organizations with foreign companies have contributed as well. By the end of 2011, 20.6% of total PV installed capacity was developed by joint ventures and bilateral organizations, and the proportion of wind power capacity was 10.2% [79]. China also has joint ventures in the small hydropower industry [44].

There are also other international financing models. Foreign governments have provided loans to the Chinese government to support renewable energy, and foreign corporations and private investors are also interested in China's renewable energy projects and capital markets.

4.3.5. South Africa

International funding can bring South Africa not only funds but also a good reputation. Seeing the great potential in South Africa's renewable energy market, many foreign banks have offered loans to finance the country's projects: Deutsche Bank underwrote 155 million euro in loans to support South African solar energy [97]; the European Investment Bank states that it loaned 44 million euros [98]; the World Bank funded 250 million dollars in the Eskom Renewables Energy Support Project in South Africa [99] and in the South African Solar One power plant and collaborated with South Africa's Industrial Development Corporation and IDC-funded Khi Community Trust [100]. Moreover, the government also encourages the independent Power Producers' Programs to look for financing from foreign investors. Solar thermal was particularly popular in the South African renewable energy market [82].

4.4. Other financing models

Other innovative renewable energy financing models are thriving in BRICS countries. For instance, the BOT model enables corporations to finance and construct renewable energy infrastructure for authorized projects on their own in China. They are also allowed to operate the project for a period, after which the project is transferred to the government. Some manufacturing companies such as Hunan Windpower are adopting this model [79,96]. Financial lease companies provide infrastructure leasing services in China. In this model, corporations can avoid the trouble of building renewable energy infrastructure, instead paying rent to financial lease companies and utilizing the infrastructure. The first financial lease company in China was established in 2009 by Mingyang Wind Power Company.

Both Brazil and India have invested a large amount of money in the clean development mechanism and hosted many projects. In addition, these governments also encourage build-own-operate (BOO) projects [90,101].

5. Problems and solutions

5.1. Problems

5.1.1. Lack of financing channels

Renewable energy development is still at an early stage in the BRICS countries, and financing channels are still lacking or incomplete compared to some developed countries.

For example, a financial citizen participation model was employed in Germany. The financial citizen participation model means that legal entities, private individuals, and agricultural enterprises invest in renewable energy infrastructures through equity [102]. The European Union Emissions Trading System (EUETS) is one international carbon market for renewable energy development [103].

Most of the projects in BRICS countries depend on loans from state-owned banks. Renewable energy is still a newcomer in the capital markets. However, due to the high-risk characteristics of the renewable energy industry, most investors are unwilling to invest in this area. Innovative financing models such as financing leases and build-operate-transfer are available in China, but their application is still limited. In South Africa and Russia, there are only a few financing options, which leads to problems finding financing channels.

5.1.2. Investment shortage in small and medium-sized enterprises

Currently, BRICS country governments primarily focus on funding large renewable energy projects, and little funding goes to small and medium-sized enterprises. These must depend on loans from commercial banks. However, risks in renewable energy projects are high, and there are many uncertainties. Because commercial banks have limited funds, they are afraid of the possible losses. Consequently, small and medium-sized enterprises cannot find sufficient investment to cover the high costs. For example, small and medium-sized projects cost between 1 million USD and 20 million USD [104]. This phenomenon is common in the photovoltaic and small hydro industry. Investment shortages in BRICS countries result in slow innovation development and discourage innovative ideas.

5.1.3. Imperfect related government policies

Although the BRICS countries have all introduced preferential policies for the renewable energy industry, many of these policies need to be improved to address higher policy risks [79]. The market changes continuously and new problems and opportunities appear. However, the policies in BRICS countries cannot adapt to these changes in time. Furthermore, policies related to R & D departments and free markets are particularly insufficient.

5.2. Solutions

5.2.1. Solutions for the lack of financing channels

Financing channels for renewable energy should be increased in BRICS countries. These countries can refer to experiences in developed countries such as the United States and Germany. For Russia and South Africa, capital markets should be created and expanded to collect more funds to develop renewable energy. In the countries with an existing capital market, more channels should be adopted. Moreover, innovative financing models deserve more attention in all BRICS countries. Financing lease services, build-operate-transfer and build-own-operate projects have much development space.

5.2.2. Solutions to Investment shortages in small and medium-sized enterprises

Governments should pay more attention to small and medium-sized enterprises; creating special funding institutions and preferential policies will help these enterprises. Governments should also encourage commercial banks to lend funds to small and medium-sized enterprises by offering banks a better investment environment.

Introducing small and medium-sized programs to the public and providing investment protection and guarantees will engage more investors in financing these enterprises. A financial citizen participation model and emissions trading system similar to that in Germany [102] and the EU ETS should be employed. In this case, the investment shortage will largely be resolved.

5.2.3. Solutions to imperfect related government policies

Those departments who set renewable energy policy in BRICS countries should pay attention to the changes and the current situation in the industry. They should listen to feedback regarding new policies from the participants in renewable energy projects, including shareholders and manufacturers. This will help governments to understand the drawbacks of policies and allows them to amend policies as soon as possible.

The regional reserve ratio monetary policy (one of three potential monetary policies) is suggested as one way to increase a region's potential to develop renewable energy; these regions should put a low reserve ratio monetary policy in place. If regions with the potential to develop renewable energy can obtain loans more easily, the renewable energy enterprise fund shortage will be solved.

6. Conclusion

Renewable energy in BRICS countries is developing at a high speed. Exploitable renewable energy resources such as wind energy, solar energy and hydropower are widely available in BRICS countries. China, India and Brazil have relatively long development histories and more achievements compared to the Russian Federation and South Africa. Through decades of effort, China has now mastered many advanced renewable energy technologies, especially in the photovoltaic industry. In India and Brazil, installed capacities are increasing rapidly. The Russian Federation and South Africa are determined to develop their clean energy industries and have made satisfying progress in the early stages.

Increasing funds are being invested in the renewable energy area in BRICS countries. The main models include bank loans and institutional financing, industry funds and international financing. In BRICS countries, China is the leading country in terms of the total investment amount and the maturity of the financing models. The models in India and Brazil are also functioning effectively to collect funding. However, because Russia and South Africa are still in the early stage of renewable energy development, their financing models still need to mature. In BRICS countries, most renewable energy projects raise funds from debt; these funds are mainly provided by banks and related institutions, which offer developers very low-interest loans. Industry funds also play an important role in renewable energy financing. The governments of BRICS countries are all devoted to developing renewable energy, and they allocate special funds to support research and to exploit projects. In addition, subsidies are given to developers and consumers, which is considered to be an effective incentive policy. Stocks and bonds for renewable energy corporations have appeared in China's capital markets and raised large amounts of money. In China, India and Brazil, VC and PE also become increasingly popular for financing renewable energy. All five countries are adopting the international financing model, with funds coming from foreign governments, international banks and foreign private investors. Furthermore, other financing models are emerging in BRICS countries, such as BOT and BOO.

BRICS countries are still exploring and accumulating experience in the renewable energy area. Some problems have inevitably appeared in the process of development, especially in the Russian Federation and in South Africa. The primary problems in BRICS countries are the lack of financing channels, investment shortages in small and medium-sized enterprises and imperfect government policies. There are also some solutions to current problems such as creating new financing channels, providing government support for small innovative enterprises and amending policies in a timely manner. For BRICS countries, there is still much progress to be made in renewable energy development.

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