Renewable Energy Resources Potentials in G8 and BRICS

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Abstract. Renewable energy is emphasized globally due to its potential to contribute to economy and energy sustainable development, as well as mitigate the climate change. Developed and developing countries have set their sights on renewable energy as increasing exhaustion of the fossil energy and deterioration of environmental problem. This article focuses on concise summary and statistic of renewable energy resources potentials, including solar energy, wind energy, bioenergy, geothermal energy, and hydropower. Meanwhile, it provides the renewable energy development status of G8 (US, UK, France, Germany, Italy, Canada, Japan, Russia) and BRICS (Brazil, Russia, India, China, and South Africa) countries. The result indicates that renewable energy resources are abundant, especially in China, the US and Russia. Each country has its own resources advantage. China has abundant renewable energy resources but still needs to accelerate renewable energy technology innovation. At last, suggestions are proposed for policy makers on renewable energy penetration.

1. Introduction

Renewable energy resources have lower emissions, are renewed in continuous cycles and are available in nature to utilize[1]. Renewable energy has become essential all over the world, and the use of renewable energy resources is growing rapidly for energy generation. Several studies indicate that these will have a huge contribution in the future[2]. Thus, renewable energy resources related issues are investigated.

Mbungu N. T et al present an overview of the integration of renewable energy resources and addresses the different contexts of using renewable energy resources and grid-connected applications[3]. Nygaard et al investigate the linkage between natural resources, economic development, renewable energy and CO$_2$ emissions in BRICS countries[4]. Wind resources contribute more in energy production than solar resources do[5]. Some researcher have analyzed conditions for optimal use of multiple sources of a renewable resource[6]. The potentiality of utilizing renewable energy resources are evaluated, and the renewable energy resources are ranked in Korea[7]. An evaluation model to select the most appropriate renewable energy resources in Turkey has been developed[2]. The various renewable energy resources has been assessed to diversify the electricity generation from fossil fuels to renewable energy[8]. Renewable energy in the electricity mix will make an important contribution in the transition[9]. Moreover, a novel approach to the preliminary, low-cost, national-scale mapping of wind energy, solar energy and certain categories of bioenergy resources in developing countries is presented[10].

The characteristics of renewable energy resources potentials determine the balanced energy development policy, realizing largely optimal allocation of energy resources. The aim of the assessment of renewable energy resources is to provide the resources potentials for renewable energy development, as well as contribute to energy planning. On the one hand, we should make full use of our country’s resource advantages to meet the growing electric power demand. On the other hand, it is
necessary to focus on the development of renewable energy power technologies which are of low resource dependence and high technology dependence.

2. Renewable energy resources potentials

This article focuses on the statistical calculation of the renewable energy resources of G8 and BRICS countries. The statistical methods vary among different renewable energy resources. The data originate from IEA, EIA, Survey of Energy Resources, global wind energy council and other international energy websites and energy reports.

Throughout the process of renewable energy development, most countries preferentially developed the renewable energy with high natural resources dependence and high technological maturity. For instance, Japan prioritizes the development of geothermal power and solar power. The United Kingdom focuses on the development of wind power, biomass power and hydropower. The impact of renewable energy resources on economic factor has been investigated in my previous research. The renewable electric power generation performance index (REPPi) based on renewable resources was defined[11]. The correlation between REPPi and macroeconomic condition, technological progress, electricity consumption and R&D investment were analyzed. Specifically, the impact of REPPi on per capita GDP, patents, electricity consumption, and new and renewable energy R&D investment ratio were investigated. We found that technological progress and new and renewable energy R&D ratio had significant effects on promoting the improvement of REPPi. However, per capita GDP effect on REPPi of some countries is not significant recently, which indicates that REPPi of those countries is not simply decided by economic development. In China, renewable energy electric power generation performance is mainly impacted by per capita GDP and electricity consumption.

The Group of Eight (G8) is an assembly of the world's largest developed economies that have established a position as pacesetters for the industrialized world. G8 is also an economic and political organization designed to bring about discussion and effect change among the world's most powerful nations. Brazil, Russia, India, China, and South Africa (BRICS) ranked among the world's fastest-growing emerging market economies for years, thanks to low labor costs, favorable demographics and abundant natural resources at a time of a global commodities boom. G8 and BRICS could represent characteristics of developed and developing countries. Therefore, G8 and BRICS are chosen to be research countries.

2.1. Solar resources

Solar energy refers to the conversion of the solar radiation into more usable forms, such as electricity and heat. Solar energy is the most abundant permanent energy resources on earth and it is available for use in its direct (solar radiation) and indirect (wind, biomass, hydro, ocean etc.) forms. The irradiation is the radiation energy incident over a specific area for a given period of time. It is expressed either in W*s/m^2, J/m^2 or very often in Langley (Ly)[12]. As specific,

\[ 1\text{ Ly} = 1\text{ cal/cm}^2 = 4.184\text{ E}^4\text{ J/m}^2 \]  

(1)

The annual solar radiation (MJ/m^2) is used to represent the amount of solar radiation throughout the year internationally. The average solar radiation intensity in the Earth's orbit is 1367kw/m^2 (solar constant). The solar energy resources abundance is generally expressed by the total annual radiation (in Kcal/cm^2 * a or kw/cm^2 * a) and the total hours of sunshine throughout the year.

The distribution of solar energy resources on earth is related to the latitude, altitude, geographical and climatic conditions of specific areas[12]. From the view of global, the world's most solar-rich regions are southwestern United States, Africa, Australia, China's Tibet, Middle East. In the comprehensive assessment of the solar energy resources of countries, cities with relative longer sunshine duration should be selected, which can represent characteristics of each country's annual sunshine duration. Thus, Yuma of the US, Saskatchewan of Canada, Sicily of Italy, the Koln of Germany, Roussillon of France, England of UK, Nagano of Japan, St. Petersburg of Russia, Bahia of Brazil, Kolkata of India, Xinjiang of China, Johannesburg of South Africa are selected. The solar energy resources of countries are shown in Figure 1.
2.2. Wind power resources

Wind Energy can be defined as the kinetic energy of flowing air that can be harnessed with the help of wind turbines[2]. Wind energy has been utilized by man for thousands of years, initially to provide mechanical energy and now to provide electricity. Effective wind energy is defined as the wind energy possessed by the effective wind speed within a certain period of time. Wind Power Density (WPD) is a quantitative measure of wind energy available at any location. It means annual power available per square meter of swept area of a turbine[13]. Wind power density depends on the power per unit area. The general formula to calculate the wind power density is as follows[14]:

**Kinetic Energy definition:**

\[ KE = \frac{1}{2} m v^2 \]  

Where, \( m \) is the mass of flowing air (kg); \( v \) is the speed of air flow (m/s).

**Power is KE per unit time:**

\[ P = \frac{1}{2} m v^2 \]  

**Fluid mechanics gives mass flow rate is density times volume flux:**

\[ \frac{dm}{dt} = \rho A v \]  

Where, \( \rho \) is the density of air, \( A \) is an imaginary area that is perpendicular to wind.

Thus, \( P = \frac{1}{2} \rho A v^2 \)  

the value of \( \rho \) changed according to the height (rarely)

From the global perspective, areas with rich wind energy resources are west coast of the Atlantic Ocean, especially United Kingdom and Ireland. The area with better wind energy resources is on the north coast, followed by middle and high mountains areas. See Table 1.

**Table 1. Global wind energy resources distribution**

| Area                          | Land area (km²) | Land area with gentle breeze to moderate gale (km²) | Proportion of land area with gentle breeze to moderate gale (%) |
|-------------------------------|-----------------|----------------------------------------------------|---------------------------------------------------------------|
| North America                 | 19339           | 7876                                               | 41                                                            |
| Latin America and the Caribbean | 18482           | 3310                                               | 18                                                            |
| Western Europe                | 4742            | 1968                                               | 42                                                            |
| Eastern Europe and CIS        | 23049           | 6783                                               | 29                                                            |
| Middle East and North Africa  | 8142            | 2566                                               | 32                                                            |
Although Germany is not the country with the most abundant wind energy resources, its wind power keeps leading the world since 1998. In this study, the wind energy resources potentials are expressed by total wind energy resources that can be developed and utilized. The wind energy resources potentials of counties are seen in Figure 2.

**Figure 2.** Wind energy resources potentials

Data source: Global Wind Energy Council

### 2.3. Bioenergy resources

Bioenergy includes traditional biomass (forestry and agricultural residues), modern biomass and biofuels. It represents the transformation of organic matter into a source of energy, whether it is collected from natural surroundings or specifically grown for the purpose[15]. In developed countries, bioenergy is promoted as an alternative or more sustainable source for hydrocarbons, especially for transportation fuels, like bioethanol and biodiesel, the use of wood in combined heat and power generation and residential heating. In developing countries, bioenergy may represent opportunities for domestic industrial development and economic growth[15]. China is the world leader in bioelectricity generation, followed by the United States, Brazil, India and Germany. Biofuels production is dominated by the United States and Brazil, which together produced 69% of all biofuels in 2018[16]. Bioenergy markets and industrial activity are driven strongly by policy, but trade patterns, especially for transport biofuels, are influenced greatly by changing import tariffs and other similar measures[15].

The bioenergy resources potentials are calculated by the biomass resources that can be converted into energy use[17]. Bioenergy resources potentials of countries are seen in Figure 3.

**Figure 3.** Bioenergy resources potentials
2.4. Geothermal energy resources

Geothermal energy can be defined as the heat energy extracted from the depths of earth as a result of the temperature and pressure difference with the ambient conditions. These heat reservoirs can be found in form of water, wet or dry steam or dry rocks at higher temperatures in subterranean rocks, depending on local geologic structure[2]. Geothermal global output is estimated to be 75TWh for heat and 75TWh for power[15]. Geothermal energy contributes a small proportion of the world’s primary energy consumption and accounts for less than 1% of electricity generation.

At present, the two main types of geothermal resources that can be developed and utilized are geothermal steam and geothermal water. Geothermal resources data in the article refer to the direct use geothermal resources of 2015, since geothermal resources potentials are counted every 5 years[18]. Global geothermal energy resources are mainly distributed in following regions[17], Pacific Rim, Mediterranean and the Himalayas geothermal zones, the mid-Atlantic ridge geothermal zone, Red Sea, Gulf of Aden, and Great Rift Valley geothermal zones, and other geothermal areas such as Central Asia, Eastern Europe, Jiaodong and Liaodong Peninsula, and North China Plain. Geothermal resources potentials of countries are shown in Figure 4.

![Figure 4. Geothermal resources potentials](image)

2.5. Hydropower resources

Hydropower is the gravitational energy that is contained in rivers and reservoirs in mountainous regions[2]. Potentials have typically been categorized as gross theoretical, technically feasible or economically feasible. The hydropower resources in this article refer to technically feasible potentials. Hydropower is the leading renewable source for electricity generation globally, supplying 71% of all renewable electricity[15].

Hydropower is currently the most mature renewable energy power generation technology, which is recognized as the most clean and renewable energy with large scale development. Asia has the most abundant hydropower resources, which accounts for 36% of the world, followed by Africa, Latin America, and North America. Significant new development is concentrated in China, Latin America and Africa[15]. Oceania has the least hydropower resources, only accounting for 2% of the world. Significant new development is concentrated in China, Latin America and Africa. The top 5 largest markets for hydropower in terms of capacity are China, Russia, the US, Brazil and Canada[19]. The hydropower resources potentials are shown in Figure 5.
3. Conclusions
Renewable energies play an important role in mitigating climate change and energy planning. Thus, the statistic of renewable energy resources is the foundation of renewable energy application. Renewable energy sources are abundant, widely distributed and with significant environmental benefit. Meanwhile, most renewable energies technologies are mature and are easily accepted by people. The distribution of solar energy resources is largely related to the latitude, altitude, geography and climate. The US has the most abundant solar energy resources, followed by India and China in G8 and BRICS countries.

Wind energy resources are abundant globally, and the development prospect is immense. The US has the most abundant wind energy sources, followed by Russia and China in G8 and BRICS. The most successful country of wind energy utilization is Germany. Russia has the richest bioenergy resources, followed by the US, Brazil and China in G8 and BRICS. China leads the world in bioelectricity generation. Biofuel production is dominated by the United States and Brazil. Bioenergy markets are driven strongly by policy and influenced greatly by import tariffs.

China has the most abundant geothermal resources, followed by the US and Japan in G8 and BRICS. Geothermal energy contributes a tiny proportion of the world’s primary energy consumption and accounts for less than 1% of the electricity generation. China has the richest hydropower resources, followed by Russia and the US in G8 and BRICS. Hydropower is the leading renewable source for electricity generation globally. China has considerable renewable energy resources. Confronted with the fossil energy exhausted and environment deterioration, energy planners should increase the renewable penetration by incentive electricity generation from renewable energies. Meanwhile, it is essential to adopt strong public policies and conduct researches to move forward the application of renewable energy technologies. Renewable energy resources exploration has tremendous perspective to mitigate energy and environment crisis, as well as realize sustainable development.

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