A Short Review of Renewable Energy Generation: Sustainable Development, Successful Lessons from Leading Countries

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Abstract Renewable energy (RE) is the most priority issue to keep global sustainable development with a non-pollution environment, non-gas emissions, and no global warming. Renewable energy is generated from renewable sources that immensely exist in nature such as wind, solar, ocean, bioenergy, and geothermal energies instead of fossil energy sources with many harmful problems for human health and environment. This paper reviews recently RE technologies and successful lessons from applying modern science and technology in developing renewable energy for a sustainable economy, society, and industrial development in leading countries of sustainable energy development. The results hope that renewable energy will be bloomed in research and practical application all over the world.

Keywords Energy · Renewable energy · Sustainable energy · Sustainable development

1 Introduction

Most countries need a huge amount of energy for social and economic development demand. Traditional energy that comes from fossil energy resources by using technologies with toxic wasted pollutions of carbon dioxide or sulfur gases through

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burning or power plant techniques, has been still numerously used in over the world. The use of traditional energy is parallel with a long time negative consequences of environmental pollution, gas emission, climate change, and human health effects. Renewable energy, which comes from renewable energy resources of solar energy and nature energies with non-toxic pollution and human health protection, is quick development based on sustainable energy sciences and technologies for converting renewable energy sources into useful energy recently. These methods include renewable energy conversion techniques of wind power, solar photovoltaic, biofuels, hydropower, and geothermal energy technique [1–7]. With outstanding advantages, the renewable energy is rapidly exploiting and applying for sustainable development in all fields of economy, society, health care, transportation, and industry. Many countries show strong movements in the development and application of renewable energy in replacement of traditional energy by renewable energy such as China with the planning of the electricity of renewable energy of 139,450 GWh in 2050 [8], developing policy and technology related to renewable energy with solar home systems in Sub-Saharan Africa [9], developing advanced technologies in renewable generations for island power grids [10], building a smart energy city with one hundred percent renewable energy for Denmark and Europe in 2050 [11], building the renewable energy policy with regional allocation in China to get carbon neutralization in 2060 [12], and providing a roadmap for sustainable development in South Korea with transition scenarios toward the renewable energy by 2050 [13]. This paper reviews recently renewable energy technologies and successful lessons from the strategy of applying modern science and technology in developing and exploiting renewable energy for sustainable energy development. The results hope that renewable energy will be strongly developed and exploited in countries all over the world.

2 Renewable Energy Generation

Renewable energy generation (REG) changes renewable energy sources into valuable energy like electricity. Table 1 shows the renewable energy production from the top 5 countries in the years of 2019, 2020, and 2021. China goes the first position with REG of 742×10^3 gigawatt-hours (GWh) in 2019, 863.2×10^3 GWh in 2020, and 1152.5×10^3 GWh in 2021, respectively. The United States stands the second place with REG of 483.7×10^3 GWh 547.7×10^3 GWh, and 624.5×10^3 GWh in the years of 2019, 2020, 2021, respectively. Germany comes the third place with REG of 220.6×10^3 GWh in 2019, 231.8×10^3 GWh in 2020, and 217.6×10^3 GWh in 2021, respectively [14].

Table 1 The renewable energy generation from the top 5 countries (Gigawatt-hours)

Country	Year		
	2019	2020	2021
China	742×10^3	863.2×10^3	1152.5×10^3
US	483.7×10^3	547.7×10^3	624.5×10^3
Germany	220.6×10^3	231.8×10^3	217.6×10^3
India	141.1×10^3	152×10^3	171.9×10^3
Brazil	117.6×10^3	126.5×10^3	144×10^3

3 Sustainable Energy Development

Sustainable development is one of the first criteria of social development. Most of the fields need the energy to develop. Some areas have also contributed to sustainable energy development such as information technology, environment technology, power grid. That, renewable energy technology has a vitally important role in sustainable energy development strategies in over the world. Some research groups have developed new models or indexes to enlarge services of sustainable energy development such as using multi-dimensional indicators to measure sustainable energy development [15], using tools of internet of thing in sustainable energy systems [16], using hybrid harvesters to get sustainable energy [17], and applying blockchain to the sustainable energy systems [18]. To get sustainable development related to renewable energy, some dimensions need to use to estimate the satisfaction levels of society, economy, environment, energy, and technology. Some criteria also need to use to measure the application ability of renewable energy such as resource potential, energy efficiency, energy grid, energy variability, cost, carbon dioxide emission, energy conversion efficiency, employment, and environmental impact. Figure 1 shows the relationship between renewable energy, dimensions, and criteria in the sustainable development strategy.

4 Some Successful Lessons from Leading Countries

Some countries show outstanding abilities in developing and applying renewable energy in living, economy, and society. For examples: developing a framework of the service-oriented operation system for a power system in China with new technologies of communication technology, internet of things, cloud computing, and smart grid [19], transiting to renewable energy in Azerbaijan [20], using biofuels to reduce urban air pollution and CO_2 in Brazil [21], using optimization method of biogas production in Zimbabwe with anaerobic digestion [22], using the energy security and sustainable energy policy for sustainable development in Bangladesh [23], constructing a one hundred percent renewable electricity supply scenario with about 10.6 GW of solar power, 4.5 GW of wind power, and 25 GW of photovoltaic up to 2050 [24]. The

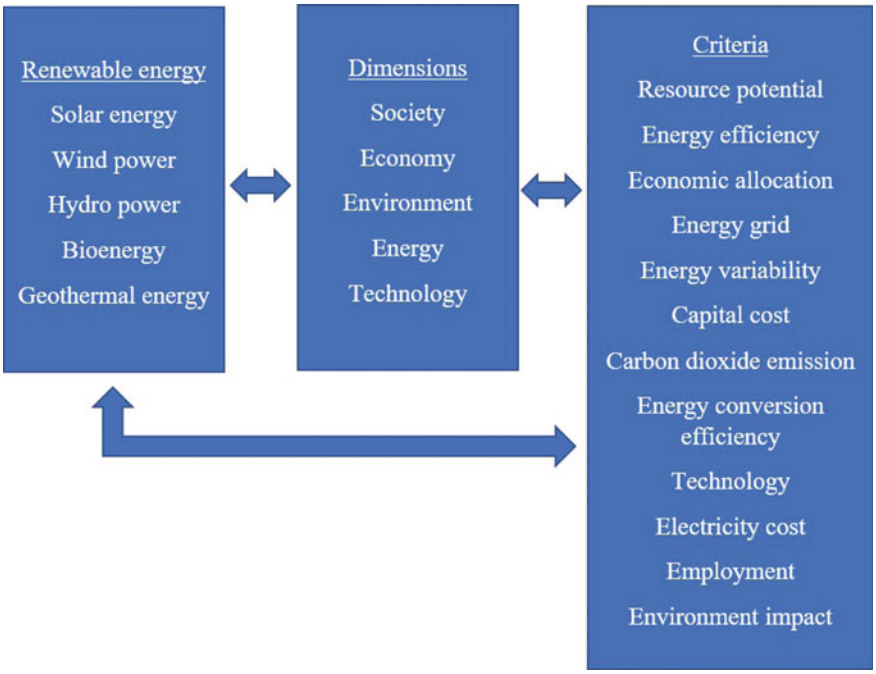

Fig. 1 The relationship between renewable energy, dimensions, and criteria in the sustainable development strategy

United States projects that renewable energy generation will increase up to 44% in 2050 from 21% in 2021 [25]. Table 2 shows the top 5 countries with the total renewable energy generation in the world in 5 years from 2017 with the first place of China with 502×10^3 GWh in 2017 and up to 1152.5×10^3 GWh in 2021 [14]. The global renewable energy generation increases from 2182.3×10^3 GWh in 2017 to 3657.2×103 GWh in 2021. Figure 2 shows the share of renewable energy generation from the 5 leading countries in the world in 2021 with the biggest place of China with 31.5%, followed by the US 17.1%, Germany 5.9%, India 4.7%, and Brazil 3.9% [14].

Table 2 The top 5 countries with the total renewable energy generation in the world in 5 years from 2017 to 2021 (Gigawatt-hours)

	2017	2018	2019	2020	2021
China	502×10^3	636.4×10^3	742×10^3	863.2×10^3	1152.5×10^3
US	417.7×10^3	451.6×10^3	483.7×10^3	547.7×10^3	624.5×10^3
Germany	194.7×10^3	204.4×10^3	220.6×10^3	231.8×10^3	217.6×10^3
India	99.1×10^3	123.9×10^3	141.1×10^3	152×10^3	171.9×10^3
Brazil	96.1×10^3	106.3×10^3	117.6×10^3	126.5×10^3	144×10^3
Total world	2182.3×10^3	2489.2×10^3	2799.2×10^3	3146.6×10^3	3657.2×10^3

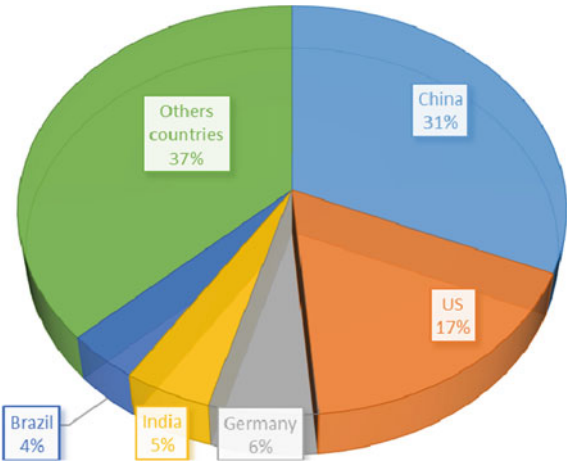

Fig. 2 The share of renewable energy generation from the 5 leading countries in the world in 2021

5 Conclusion

Renewable energy has a critically important role in the energy development strategy. Renewable energy brings long-term sustainable development with non-gas emissions, a non-pollution environment, no global warming, and saving environment. This paper reviews recent renewable energy technologies and successful lessons of renewable energy development from leading countries. The results hope that renewable energy will be strongly developed and exploited in countries all over the world.

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