Resources **2015**, *4*, 751-764; doi:10.3390/resources4040751

OPEN ACCESS

resources

ISSN 2079-9276

www.mdpi.com/journal/resources

Review

Recent Trends in Renewable Energy Resources for Power Generation in the Republic of Korea

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Academic Editor: Witold-Roger Poganietz

Received: 30 May 2015 / Accepted: 12 October 2015 / Published: 21 October 2015

Abstract: The global demand for renewable energy in recent decades has continued to increase, despite adverse economic conditions such as world economic recessions, trade disputes, and falls in gas and oil prices. During this period, the United States and Europe have led the development of renewable energy technologies, but now emerging countries such as China, Brazil, India, and the Republic of Korea are also been actively participating in developing and deploying renewable energy. For example, since 1989, the Korea Electric Power Corporation has built a well-known test site for the application of renewable energy resources, including 500 kW photovoltaic systems with smooth integration into power grids in the Gochang area. The main objects of this study are (1) to review the recent trends in renewable energy systems, including solar, wind, bioenergy, hydroelectric, and tidal power, for electric power generation developed in Korea and (2) to introduce the test sites in Korea. For this purpose, this study examines the current activities of industry and government in Korea and compares them with global trends.

Keywords: renewable energy; solar; wind; bioenergy; hydroelectric; tidal power

1. Introduction

The global demand for renewable energy has continued to increase over the past few decades, but the rate of growth has decreased due to adverse economic conditions such as the global economic recession, various trade disputes, and falling gas and oil prices [1,2]. In addition, some American states and European countries have reduced their political support for renewable energy after the recent fall in global oil and gas prices [3]. Therefore, there is a concern that the competitiveness of renewable energy as a source for electric power generation will not increase and that global investments in the renewable energy industry may freeze [1]. However, global investment in renewable energy has grown continuously over the past several decades, even in economic hard times. Furthermore, some investors insist that it is timely to invest in the renewable energy industry while closing the gap with conventional generation sources such as coal-, gas-fired, and nuclear power generation [2]. For example, in the "New Policies" scenario of the 2013 World Energy Outlook, in 2035, the global demand for renewable energy may grow to 77% above the level of 2011 [2]. Although the United States and Europe have led the development of global renewable energy during the past few decades, now emerging countries such as China, Brazil, India, and Korea have also been actively participating in the development and deployment of renewable energy resources [1,2]. Table 1 shows the total installed capacity of renewable energy generation for each country in 2013, which indicates that China, Brazil, and India as well as the United States and Europe are leading the global renewable energy revolution.

Table 1. Total installed capacity of renewable energy generation in 2013 [1].

Type	1st	2nd	3rd	4th	5th
Renewable Including Hydro	China	USA	Brazil	Canada	Germany
Renewable Excluding Hydro	China	USA	Germany	Spain/Italy	India

During this trend of continual growth of global demand for renewable energy in recent years, Korea has expanded renewable energy resources for power generation. For example, the Ministry of Trade, Industry, and Energy, a branch of the government in charge of regulating economic policy, announced its fourth mid- and long-term plan that enhances the development and application of renewable energy resources beginning in September, 2014. In 2012, the total generation capacity of renewable energy in Korea was 3.66% of the total domestic generation capacity, which is very low compared to the other countries of the Organization for Economic Cooperation and Development (OECD) [3]. Table 2 indicates total electric energy generated from renewable energy resources in percent proportional to the total generation capacity of OECD countries. Korea ranks 34th out of 35 countries. Note that Table 2 does not take into account fuel cells and renewable energy resources using coal liquefaction, industrial waste, and byproduct gases.

Table 2. Total generation capacity of renewable energy resources of OECD countries in 2011 [3].

Rank	1st	16th	26th	31st	32nd	34th
Country	Iceland	Germany	USA	Japan	UK	Korea
Total Generation of Renewable Energy in Percent	83.8%	11.3%	6.4%	4.6%	4.4%	1.7%

Despite a very low percentage of renewable energy resources (*i.e.*, 1.7%), the rate of growth of renewable energy for power generation in Korea shows an annual average of 46.6% for the past five years. Furthermore, the renewable energy industry of the nation has rapidly increased quantitatively. For example, the number of companies, employees, and sales in the domestic renewable energy industry have respectively increased 1.5, 1.8, and 2.0 times over the previous five years [3]. Therefore, the Korean government has forecast steady long-term growth in the renewable energy industry [3]. In addition, the cost of generating electricity from renewable energy resources has continuously decreased as a result of improved renewable energy technologies [3]. In fact, it is expected that competition between companies to occupy the renewable energy market will become much more heated [2]. Thus, the Korean government announced a plan that (1) increases political and financial support in which total energy generated from renewable energy is increased by as much as 13.4% of the total generation capacity of the nation by 2035 and (2) ensures the sustainable growth of the renewable energy industry through aggressive overseas expansion drives [3].

Since the renewable energy resources of Korea show gradual and steady growth, the objectives of this study are (1) to review the recent trends of renewable energy resources developed for electric power generation in the industry and government of the nation and (2) introduce the test sites in Korea. This will allow identification of a current profile of renewable energy resources of the nation. This review is organized as follows: Section 2 presents the current status of renewable energy resources, including solar, wind, bioenergy, hydroelectric, and tidal power. Section 3 introduces two well-known test sites for the application of smart grids and smooth integration of renewable energy resources into the power grids of the nation. Finally, Section 4 summarizes the major conclusions of this study.

2. Renewable Energy Resources in the Republic of Korea

2.1. Solar Power Generation

Solar power generation is the fastest-growing technology in electric power generation [4]. Europe and the United States have played a major role in this rapid growth beginning in the 2000s [4]. However, whereas the European solar power market diminished because of the financial crisis of Europe in 2011, emerging markets, including the large solar power plants of Asia and North America, have rapidly grown [4]. At the end of 2013, as a result of a rapid growth of solar power, the global installed capacity for solar power increased to 139 gigawatts (GW) [2]. In addition, a number of countries around the world have adopted various government-driven strategies for the growth of renewable energy and their objectives are to achieve energy independence, create a new future industry, and prepare for the United Nations Framework Convention on Climate Change [1]. In other words, these strategies aim to promote the growth of solar power generation by gaining financial and political support as well as by increasing public awareness. For example, government-driven policies include (1) a feed-in tariff (FIT) scheme in which a government purchases electricity generated from renewable or low-carbon resources, particularly wind and solar, at fixed reference prices during a given period (e.g., 15 to 20 years) and (2) a renewable portfolio standard (RPS) that is a regulatory method for energy producers to produce or sell a specified percentage of electricity from renewable energy resources [2]. Furthermore, as a result of the advance of solar power technologies and a continuous increase in PV module shipments (which can be seen in PV learning curves over the past three decades), the cost of solar power generation has continuously decreased, often even reaching grid parity in the sunny areas of the world without government incentives or subsidies [5].

2.1.1. Policies Supporting the Solar Power Industry of the Republic of Korea

As the global demand to use renewable energy resources, particularly solar power, as replacements for conventional fossil-fuel generation continuously grows, Korean industry, and particularly the Korean government, has demonstrated substantial interest in policies affecting solar power generation. For example, the government has developed aggressive strategies for the development of the green energy industry in order to (1) close the technological gap that exists between Korea and other developed countries and (2) build a financial and institutional support system that enhances research and development as well as the industrialization of renewable energy technologies for export markets. Next, the government has invested a total of 40 trillion KRW (about 36 billion USD) in the renewable energy industry of the nation from 2010 to 2015 [2]. It had also operated a FIT scheme policy for several years to support solar power, which was discontinued from 2012 [5], at which a RPS was taken effect. Finally, in 2014, the government announced its fourth renewable energy plan where total energy produced from renewable energy resources will increase to 13.4% of the total electric energy production of the nation by 2035, 14% of which will be generated from solar power plants [3].

2.1.2. Technology, Industry, and Market of Solar Power Generation

In 2013, the total installed capacity of solar power plants of Korea was 445 megawatts (MW), which is relatively small compared to a global capacity of 136,697 MW [2]. Before then, the nation had focused on solar power modules and systems integrated to power grids that have relatively low barriers to entry, so it achieved a remarkable growth in a short period [5]. In the case of polysilicon, ingot, and wafer, which have relatively high barriers and require the investment of large capital, OCI, a Korean green energy and chemical company founded in 1959, has increased production capacity in these areas since 2007 [5]. In 2012, the Korean global market shares of the polysilicon, ingot and wafer, cells, and modules of the nation were 17.3%, 4.9%, 3.0%, and 5.4%, respectively [2]. Although Korean technology and production capacity have gradually improved, they are still not at the level of other emerging countries [5]. In order to overcome this situation, Korean solar companies are actively entering foreign markets by designing, constructing, and operating solar power plants in the form of engineering procurement and construction (*i.e.*, not a simple export product). Figure 1 shows large solar power plants developed by Korean companies around the world.

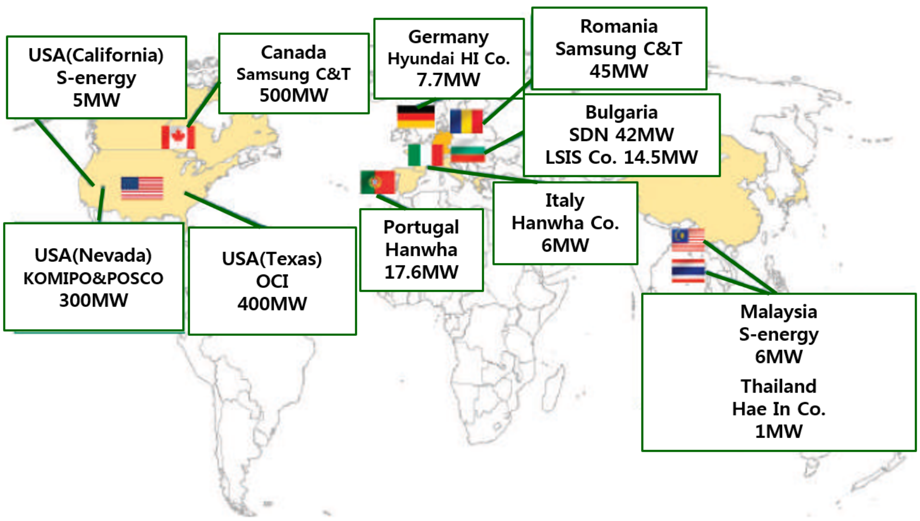


Figure 1. Large solar power plants developed by Korean companies around the world [2].

2.1.3. Current and Future Status of Solar Power Generation

The total installed capacity of solar power plants of the nation significantly increased between 2006 (when the government started a FIT scheme) and 2008 [2]. After that, because of the characteristics of temporary FIT schemes that the government pursued, the annual installed capacity of the nation decreased by 2011 [2]. However, then, because the government instead adopted a RPS rule, it has dramatically increased, even it reached 1.5 GW at the end of 2013. Figure 2 indicates the total annual and cumulative installed capacity of solar power plants of the nation in MW from 2003 to 2013. With the financial and institutional support of the government, the solar power industry of the nation has continuously invested in the research and development of technology, actively entered the foreign markets, and gradually increased solar power generation, as shown in Figure 2. Furthermore, Table 3 shows the target rate in relation to renewable energy sources until 2035 specified in the fourth renewable energy plan announced by the Korea government in 2014. Through this table, it can be expected that the total installed capacity of solar power plants of the nation will continuously increase.

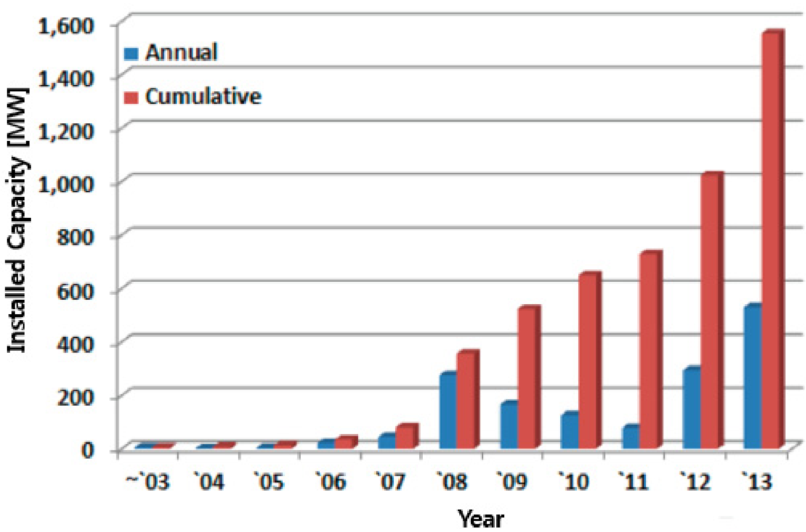


Figure 2. The annual & cumulative installed capacity of solar power plants from Korea in MW [2].

Table 3. The target rates of renewable energy sources in the fourth renewable energy plan announced by the Korean government in 2014 [3].

Renewable Energy Source	**Year**			
	2012	**2014**	**2025**	**2035**
Solar power	2.7%	4.9%	12.9%	14.1%
Wind power	2.2%	2.6%	15.6%	18.2%
Bioenergy	15.2%	13.3%	19.0%	18.0%
Ocean power	1.1%	1.1%	1.6%	1.3%

2.2. Wind Power Generation

Wind power generation has started in Europe and North America, mainly as a means of reducing greenhouse gas emissions, in accordance with the United Nations Framework Convention on Climate Change, and coping with the highly unstable prices of fossil fuel. The total installed capacity of wind power plants in the world has increased to 318 GW from 2004 to 2013, which is 19 times of its capacity in 2004 and accounts for the largest proportion of renewable energy for electricity generation since 2009, excluding hydroelectric power [2]. Technologies for such wind power generation have been initially developed in Europe and North America. In fact, the top ten countries using wind power occupy 85% of the global market [1]. However, other countries are also creating new markets for wind power. For example, as of 2013, commercial wind power began in 85 countries, at least 71 countries of which have installed more than a capacity of 10 MW [4]. Recently, because of the financial crisis of Europe and a slowdown in the demand for wind power in North America and Europe, the annual growth rate of the wind power industry has stabilized at a low level [6]. However in emerging countries, including China, the demand for wind power has dramatically increased, showing industry growth rates polarized between developed and developing countries [6]. Although the wind power industry has shown a slight decline in installed capacity because of the financial crisis of Europe and global recessions, it will continue to grow by an annual rate of 60 GW and is expected to reach a total capacity of 1000 GW by 2030 [4].

2.2.1. Wind Farms in the Republic of Korea

In 2013, the potential capacity of onshore and offshore wind power plants of the nation was 3.6 GW and 8.8 GW, respectively, and the total accounts for 0.19% of all generation capacity of Korea [6]. This amount being small can be explained by (1) the domestic market for wind power being too small or restrictive or (2) the government failing to link policies that increase technical and market maturity to the wind power industry [2]. However, recently, the nation has started to develop onshore wind farms that have been pending because of environmental regulations [2]. Since then, the wind power industry has gradually increased in size. For example, Doosan Heavy Industries and Construction, one of the largest Korean heavy industrial companies established in 1962, along with the Korea Institute of Energy Research, developed a 5 MW offshore wind farm in a research park of the Jeju Island from 2011 to 2012.

In addition, in 2011, the Korea Electric Power Research Institute conducted a feasibility study on mid-capacity offshore wind power plants to be installed in the surrounding sea to develop large scale offshore wind farms. Based on the study, the government announced a comprehensive plan that develops 2.5 GW offshore wind farms on the southwest area of the nation [6]. Local municipalities also announced a plan for a 5 GW onshore and offshore wind farm (in the South Jeolla province), a 40 MW pilot wind farm (in the North Jeolla province), a 20 MW offshore wind farm (in the Busan area), and a 2 GW offshore wind farm (in the Jeju island) [2]. Figure 3 shows examples of onshore and offshore wind farms in operation.

(**a**) (**b**)

Figure 3. (**a**) Onshore wind farm in the Yeongdeok Province in Korea; (**b**) Offshore wind farm in the Jeju Island in Korea.

2.2.2. Industry Trends and Technological Developments in Wind Power Generation

The technical development of wind power generation in Korea has been driven by the government. The government's support has considerably increased since 2009 and based on this support, the significant improvement of wind power generation has been observed [6]. For instance, a 2.5 MW turbine has been developed and commercialized by Hyundai Heavy Industries and Samsung Heavy Industries, and 5.5 MW and 7.5 MW turbines are currently in the process of certification [2]. Also, Deawoo Shipbuilding and Marine Engineering and STX have been trying to improve their wind power technology by acquiring shares of Dewind in Germany and Harakosan in Netherlands, respectively [2]. Nevertheless, the level of wind power generation technology of Korea has remained at only 83.3% of that of European countries [2]. Because of the distinct characteristic of Korea highly dependent on exports, a higher technical level needs to be achieved. Table 4 compares the technology levels of wind power generation of Korea to four countries.

Table 4. Technology levels of wind power generation of five countries [2].

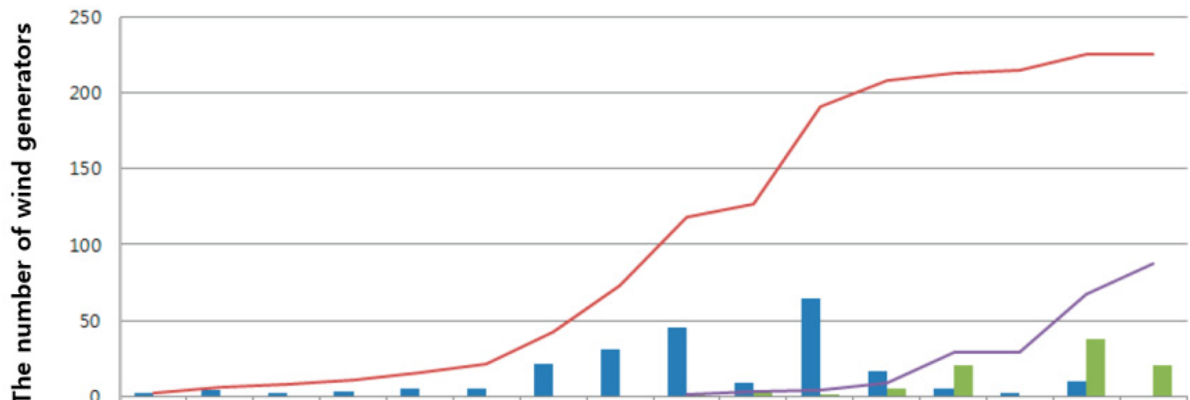
Korea		USA		Japan		Europe		China	
Relative Level	Technology Gap	Relative Level	Technology Gap	Relative Level	Technology Gap	Relative Level	Technology Gap	Relative Level	Technology Gap
83.3%	1.4 year	94.7%	0.44 year	94.0%	0.5 year	100%	0 year	80.3%	1.65 year

Through cooperation with international companies, efforts to reduce the technology gap and to secure competitiveness in the field have been made. First, in 2013, SKF Korea, a world-leading bearing company, provided Hyosung bearings for a turbine main shaft and the technology for an offshore wind farm to be applied to the 5 MW wind turbine that they were developing for an offshore wind farm on the southeastern coast of Korea.

In early 2014, GS E&C (Seoul, Korea) signed a contract with Alstom to install wind turbines in the Kimnyeong Wind Farm in the Jeju Island and received 10 of 3 MW onshore wind turbines. Alstom also made another contract with DaeMyoung GEC in late 2014 for the Gowon Wind Farm in the Gangwon province and provided 6 of 3 MW onshore wind turbines. Lastly, Korea Midland Power Co. (Boryeong, Korea) had an agreement with GS E&R (Anshan, Korea) in June 2014 for the 150 MW Yeong Yang Wind Farm project which is the largest onshore wind farm in Korea.

2.2.3. Deployment Status and Forecast on Wind Power Generation

There are 312 wind turbines with a capacity of 534 MW in at least 41 wind farms in Korea as of late 2013. Figure 4 shows the number of domestic and foreign wind turbines deployed in Korea in late 2013. About 70% of wind turbines are foreign products in terms of cumulative number, but the number of domestic turbines has been increasing each year.



	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Number (Foreign)	2	4	2	3	5	5	21	31	45	9	64	17	5	2	10	0
Number (Domestic)									1	2	1	5	20		38	20
Cumulative Number (Foreign)	2	6	8	11	16	21	42	73	118	127	191	208	213	215	225	225
Cumulative Number (Domestic)									1	3	4	9	29	29	67	87

Figure 4. Number of domestic and foreign wind turbines in Korea [2].

According to the "Second National Basic Plan for Energy" released by the Korean government, 11% of total energy will be provided by renewable energy, with wind power generation that accounts for 20% of total renewable energy. Also, the "Fourth Renewable Basic Plan for Energy" announced in 2014 mentions deregulation to promote wind power, to increase in investment costs, to build a wind power generation test bed. Therefore, wind power generation in Korea is expected to grow by accumulating advanced technologies and experiences through active foreign technology acquisition and penetration into overseas markets. This prediction is supported by the target rate in Table 3 mentioned above.

2.3. Bioenergy

Bioenergy refers to renewable energy made available from biomass such as biological or organic materials. Bioenergy is the most feasible because of abundant resources and the availability of application technologies [1]. Bioenergy consumption has been increasing in heating and generation [1]. The total amount of bioenergy generation in the world was 1.5 GW in 2013, and its market is expected to grow up to 185.3 billion USD by 2021 [4]. However, it has been observed that the growth rate of bioenergy is decreasing as the deployment of other renewable energies with high price competitiveness is increasing [7].

2.3.1. Trends in the Bioenergy Market

The bioenergy market in Korea has been gradually expanding along with the implementation of policies for deploying renewable energies [7]. Thus, the bioenergy market in Korea is expected to grow from 1 trillion KRW (about 0.9 billion USD) in 2011 up to 4.5 trillion KRW (about 4 billion USD) by 2020, and especially in markets for electricity and transportation fuels which are being promoted by policies by the government [4]. Upon implementing the RPS, a regulation that requires an increase in the production of renewable energy, Korean power plants have tried to meet the standard with solid and liquid biofuels. Thus, the bioenergy market has been gradually revitalized and is expected to grow until 2020 [2]. In addition, the size of the market in biofuel for transportation is about 600 billion KRW (about 550 million USD) and is expected to grow due to the implementation of a mandatory bio-diesel blend policy [7]. Furthermore, the market for bio thermal energy will be even further promoted because of a mandatory policy for renewable heat energy that will be enforced in 2016 [7].

2.3.2. Industry Trends and Technological Developments in Bioenergy

Since there are not enough available resources for bioenergy in Korea, researchers have focused on developing new resources and technologies [7]. For instance, technologies to convert endowed biomass resources to energy using organic waste and woody material are being developed. Researchers are also discovering new biomass sources and developing technologies to convert them into energy, especially focusing on marine biomass sources such as marine algae or phytoplankton [2]. In addition, Korean companies are moving into business in the production and distribution of fuels such as wooden pallets as there is a need for energy production technologies that use foreign biomass resources [7]. In fact, the size of afforestation by Korean companies in foreign countries to provide biomass is estimated about 130,000 ha in the past five years, and POSCO E&C (Pohang, Korea) won a 300 billion KRW (about 250 million USD) contract in late 2012 to build a waste-to-energy plant in Poland [8].

2.3.3. Deployment Status and Trend of Bioenergy

The endowed biomass resource in Korea is 1.1 million toe per year, and the bioenergy supply in Korea is about 1.5 million toe in 2013, which accounts for 15.8% of the total renewable energy supply. This is the second biggest following waste-to-energy due to the fact that biomass generation is considered to be the most practical means to the RPS implemented in Korea from 2012 [7]. According to the announcement from the Korea government, bioenergy supply in Korea is expected to increase continuously in the near future as the regulatory policy that limits biomass generated by power generation companies from 2015 has been suspended. However, such trends actually hinder the balanced development of the renewable energy industry in Korea. Also, this does not follow the global trend of using bioenergy to produce electric power or energy for transportation which is high value-added instead of thermal energy. Therefore, the Korean government announced to reduce the rate of biomass and improve the overall renewable energy industry in Korea through the fourth renewable energy plan [3].

2.4. Other Power Generations

Other sources of renewable power generation besides solar power, wind power, and bioenergy include hydropower and ocean energy. For hydropower, the global trend is that only small hydropower generation under 10 MW is considered to be renewable energy [1]. As of 2012, the total amount of small hydropower is estimated to be 75 GW–100 GW and is expected to grow to 201 GW by 2020 [4]. Asia is the largest user of hydropower, accounting for 61%, followed by Europe [1]. While ocean energy includes various generation technologies such as ocean wave, tidal current, and tidal range, only tidal range generation is currently commercialized. Such examples are Rance in France, Annapolis in Canada, Kislaya Guba in Russia, Jiangxia in China, and Shihwa in Korea [2]. Also, as countries like Argentina, Australia, Canada, India, and Russia are planning to build tidal power plants, the ocean energy market is expected to significantly expand in the future [2]. That is because theoretical potential amounts extracted from ocean energy in the world is estimated at total 82,950 TWh. In addition, the related generating plants with a capacity of 748 MW, taking 19% of electricity generation capacity in the world, will be constructed until 2050 [2].

2.4.1. Trends in Small Hydropower Generation

Small hydropower in Korea is rapidly increasing at an average of 18.6% per year and is expected to reach 2 GW of the total cumulative installed capacity by late 2015 [4]. The amount of small hydropower was 361 MWh per year in 2011, which is 4.4% of the entire renewable energy in Korea, and there are 108 hydropower plants in operation with 159.4 MW of installed capacity in 2013 [2]. The small hydro industry in Korea is mainly driven by public utilities and about 80% of small hydro plants in Korea are operated by public utilities such as Korea Water Resources Corporation. Oversea expansion of the small hydropower technology is also led by public utilities such as Korea Water Resources Corporation, Korea Hydro & Nuclear Power Co. (Seoul, Korea), and Korea Midland Power Co. (Boryeong, Korea) [4]. Although more domestic equipment is being used in small hydropower plants in Korea, there is still room for improvement as it is still only approximately 84% compared to other developed countries [2].

2.4.2. Trend in Tidal Power Generation

The western sea is considered to be the best place for tidal power in Korea. The total endowed resource is estimated at 6.5 MW with 0.5 GW in Garolim Bay, 1.5 GW in Incheon Bay, 0.8 MW in Ganghwa Bay, and 2.3 GW in Haeju Bay [2]. Also, the world's biggest Shihwa tidal plant with 254

MW was built in 2010 and started operating in 2012 [9]. The Shihwa tidal power plant in Figure 5 is a single current-typed generation system that uses the difference in height between high and low tides. Its annual generation is 552 GWh, which is capable of providing power to a city with a population of 500,000 [9]. Candidates considered for additional tidal plants include Garolim, Ganhwa, Inchoen, Asanman, and others. According to a report released by the Korea Institute of Science and Technology Evaluation and Planning in 2013, the technology level of tidal power in Korea is close to European countries and it is expected that tidal power will play a main role in the early ocean energy market in Korea [9].

Figure 5. Shihwa tidal power plant [2].

3. Test Sites for Smart Grids in the Republic of Korea

3.1. Test Bed for Smart Grids in Jeju Island

The most noticeable project for the application of smart grids and renewable energy resources is a test bed constructed on the Jeju Island, which included participation of 10 consortiums and 168 companies, costing a total of 64.5 billion KRW (about 59 million USD) from 2009 to 2013 [10]. The test bed accommodates five areas, including smart power grids, places, transportation, renewable energy resources, and electric services. To create a large-scale renewable energy generation complex, the Korean Smart Grid Institute installed renewable energy resources (which consist of a 1.5 MW wind farm, 15 wind farms with a capacity of 10 MW in the Haengwon area, and a 15 kW solar power plant), energy management systems, power conditioning systems, battery energy storage systems, and static synchronous compensators as shown in Figure 6 [10].

The test bed has tested the stabilization of power output generated by distributed wind farms, their islanded operation, their protection coordination to existing power grids, the improvement of power quality by the correction of power factor, and the application of energy storage systems [11]. Using the test bed, the Korean government announced a plan that will (1) test the advanced technologies and the results of research and development for smart grids and develop business models; (2) build smart grids across metropolitan areas by 2020; and (3) construct a nationwide smart grid by 2030 [10].

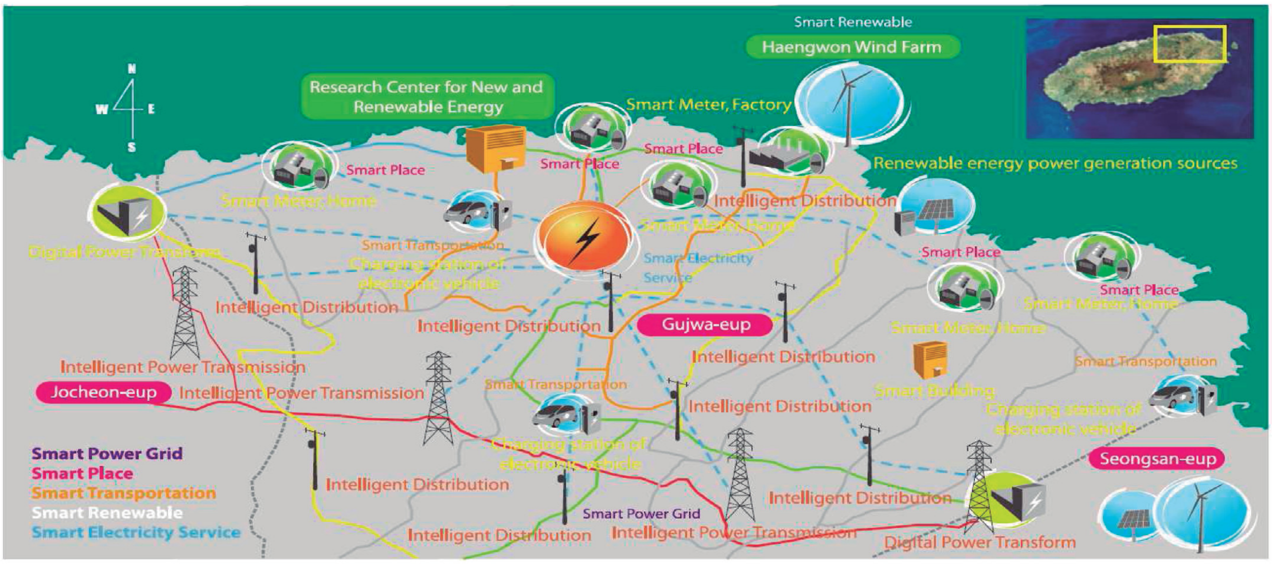


Figure 6. Test bed for smart grids on the Jeju Island [10].

3.2. Smart Grid Test-Bed in the Gochang Area

The Gochang power testing center has been established with the capability of testing of 765 kV transmission lines, and currently it has about 20 testing facilities and exhibition centers [12,13]. Its configuration was designed by KEPCO to build a world class power testing center. The center is divided into four zones based on their functions—Red, Green, Blue, and Yellow, as shown in Figure 7 [12,13]. The Red zone is to test reliability of power equipment, including 765 kV lines, substation, breakers, *etc.*, the Green zone is for grid connection technologies with renewable energies, the Blue zone is for medium-and long-term core technologies, and the Yellow zone is for consulting through tests for certification and evaluation with one of the world's largest underground cable test beds.

The Green zone exists to test renewable energy technologies and to validate renewable power equipment. It has a distributed resource (DR) grid connection test building and a photovoltaic power test bed. The DR grid connection test building built in 2009 verifies the problems of distributed resources when connected to the existing power system and is cooperated with the photovoltaic power test bed in preparation for grid connection of a high capacity DR.

The photovoltaic power test bed built in 2011 is the only facility in Korea with a 500 kW capacity. Demonstration and performance evaluation of equipment, system performance improvement, and stability testing for DR networks can be conducted in this test bed. With these testing facilities, KEPCO verifies renewable energy technologies and standardizes renewable energy connections to the grid. Also, a testing site for energy storage systems is planned to be built in 2017. This will be the place for developing operation algorithms for the energy storage systems, making an overall monitoring and control system, and verifying and testing the performance of grid connection technologies.

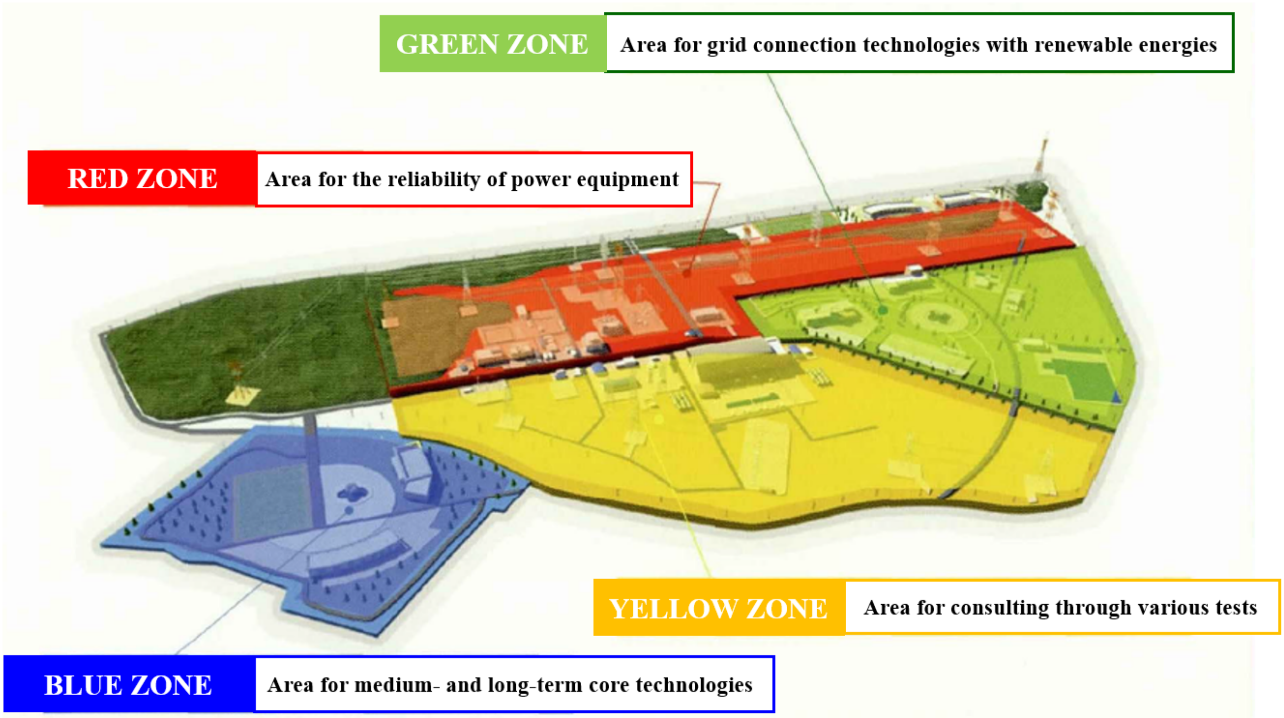


Figure 7. The configuration of the Gochang power testing center [12].

4. Conclusions

This paper reviewed trends in several renewable energy resources for electricity generation such as solar power, wind power, bioenergy, small hydropower, and tidal power in Korea. Although the supply of renewable energy in Korea is very low compared to that of other developed countries, technological development and the supply rate of renewable energy are gradually increasing because of consistent support from the government through the RPS and the "Fourth Renewable Basic Plan for Energy". Furthermore, Korean companies are expanding to overseas markets and are attempting to increase the supply level of renewable energy and to close the technology gap by cooperating with other developed countries. With government support and industry effort, Korea is trying to catapult from the lowest among the countries of Organization for Economic Cooperation and Development to among the top five in the world in terms of renewable technology.

Author Contributions

Chul-Ho Noh is the main author and is responsible for this writing of this paper. Insu Kim, Won-Hyeok Jang are the collaborators, gathering the related materials and arranging the configuration of this paper. Chul-Hwan Kim contributed to the general design of this review as a supervisor.

Conflicts of Interest

The authors declare no conflict of interest.

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