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Review

Current Policy and Technology for Tidal Current Energy in Korea

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Abstract: As global energy consumption continues to increase, the negative impact of global warming also grows. Therefore, eco-friendly energy policy is being established all over the world. Korea's energy consumption problems are further complicated by the country's high dependence on energy sourced overseas. Korean energy policy is evolving rapidly to address these problems. Korea has begun to phase out nuclear power and is focusing on developing new sources of renewable energy. So there has been substantial interest in the development of ocean energy. Of all ocean energy technologies, tidal current energy is the closest to the commercialization. Especially, the southwestern coast of Korea is the most promising candidate site for the development of tidal current energy owing to the abundant tidal current energy resource. Meanwhile, ocean energy policy is an important factor in determining the development of ocean energy. Thus, this paper presents the overview of the current status of policy and technology for the tidal current energy system in Korea. These policies explained in this paper can provide significant interest and motivation for the use of tidal current energy resources.

Keywords: eco-friendly energy policy; Korean energy policy; renewable energy; ocean energy; tidal current energy; ocean energy policy

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1. Introduction

Human fossil fuel use has serious global consequences including climate change, unstable energy supply and global warming [1]. Thus, many countries are attempting to reduce their use of fossil fuels and lower their carbon emissions. Korea is the 8th largest energy consumer in the world, having used 282 million tons of oil equivalent in 2016. Korea is ranked the 7th for petroleum consumption and 7th for power consumption [2]. These statistics combined with the fact that Korea imports 95% of its energy make it necessary to reduce national energy consumption and to invest in new sources of renewable energy. In doing so, Korea will achieve energy independence and national energy security. Japan's Fukushima nuclear accident in March 2011, the Gyeongju earthquake in September 2016 and the Pohang earthquake in November 2017 added momentum to increasing public concerns about safety and environmental energy security. In response to these concerns, Korea changed the national energy paradigm for power supply to focus on safe, clean and diverse energy resources.

Korea has four distinct seasons, spring, summer, autumn, and winter, which are influenced by the East Asian monsoon. Summer is hot and humid because of the North Pacific air mass; whereas, winter is very cold due to the effect of Siberian air mass and the northwest monsoon [3]. In addition, as Korea is a peninsula surrounded by sea on three sides, Korea possesses ocean energy resources for the utilization. The East Sea of Korea has a small tidal range, but waves are more dominant than tides. In contrast, the Yellow Sea, which is surrounded by continental China and the Korean peninsula, is shallow, with limited generation of wind-waves, but the Yellow Sea has large tidal ranges reaching up to 9 m. Northwestern sea of Korea has relatively large tidal ranges and decreasing pattern from north to south in the Yellow Sea according latitude [4]. In addition, as the southwestern sea of Korea has strong tidal currents flowing between many of the islands, there are advantages to develop tidal current energy. Especially, Uldolmok, Jang-Juk Strait and Maenggol Strait located in the southwestern sea of Korea, are evaluated as the optimal candidate sites for the development of tidal current energy [5]. The technical resource was evaluated as 4841 MW and 3497 MW in the Jang-Juk Strait and the Maenggol-Geocha Strait, respectively [6].

As mentioned above, as Korea has abundant ocean energy resources, ocean energy is recognized as one of the nation's primary energy sources in the future. However, ocean energy technology is evaluated at the early stages compared with wind energy and solar energy in Korea. There is no commercial ocean energy power plant, except for Sihwa Lake Tidal Power Plant. Technology development is still under way with the goal of commercialization. The Technology Readiness Levels of tidal current energy is evaluated at the 7th stage (demonstration) in Korea. In addition, the technology level of ocean energy was evaluated as 72.3% compared to the EU in 2010, but it increased 80.3% in 2016. The future technology level of 2020 is expected to improve to 85.4% compared to the EU [7]. Nonetheless, as there is a strong national commitment to supplying ocean energy, the Korean government is attempting to strengthen investment in technology and policy. Recently, Korea announced a new energy policy that will reduce the role of nuclear power and thermal power plants, while expanding the role of renewable energy technologies. Meanwhile, the national policy, strategy and market incentive affect the development of ocean energy. In addition, as each country owns different resources according to the characteristics of the ocean environment, they try to establish a specific national strategy for the efficient use of their own resources. However, there is still a lot of challenges to develop the ocean energy. This review paper aims to provide the overview of the current status of tidal current energy technologies and policies in Korea. This review concentrates on current national energy policies and strategies, market incentives, the development status of tidal current energy converters (TEC) and the open sea test center for TEC in Korea.

2. Ocean Energy Policy

2.1. Situation of National Power Supply

A global carbon emission trading system enabling the purchase and sale of greenhouse gas emission rights has been implemented to cope with climate change around the world. In Korea, the carbon emission trading system was implemented in January 2015 with the goal of reducing national emissions by 30% of the current 2020 estimate. The development of new and renewable energy resource is crucial to Korea's ability to achieve this goal.

Every other year since 2002, the Ministry of Trade, Industry and Energy (MOTIE) has created a basic power supply plan to forecast the long-term energy demand and expand the electric power facilities accordingly. Each biennial update assesses the previous plan, forecasts the long-term energy demand, sets demand management goals, reviews existing electric power facilities and reports greenhouse gas reductions. Power consumption in Korea steadily increases every year. The summer's high temperatures mean that summer power consumption exceeds winter energy consumption. Figure 1 illustrates the 2018 power supply outlook in Korea. The 1.96% of new and renewable energy provided by ocean energy is derived from the installed capacity of the Sihwa Lake Tidal Power Plant and the Uldolmok Tidal Current Power Pilot Plant [8]. In the case of new and renewable energy, annual energy production was calculated under the assumption of 30% system efficiency.

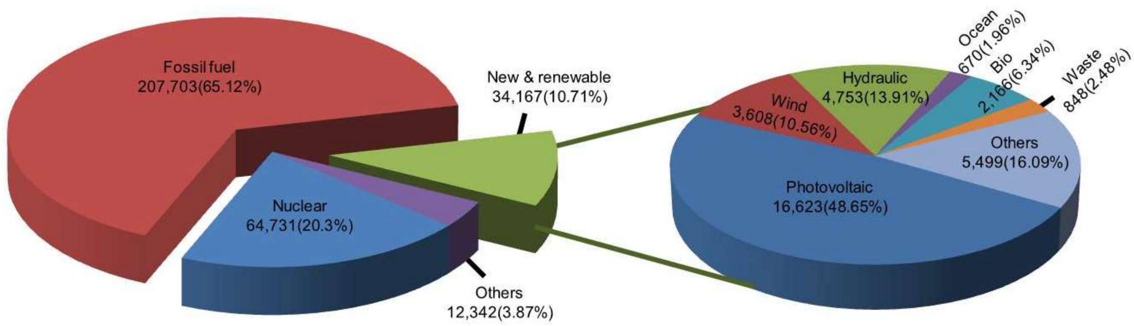

Figure 1. 2018 power supply outlook in Korea (GWh) [8].

2.2. National Energy Policy and Strategy

In Korea, various laws and policies for deregulation, investment promotion and mandatory quota system have been implemented to expand the renewable energy supply since 1988. These were bolstered by further actions in the 2000s. Recently, the Korean government has established various policies to foster new energy industries. The national energy paradigm for power supply and demand has also changed to focus on safe and eco-friendly energy sources. However, it is difficult to rely on private industry for development because ocean energy has many technological and economic risks. Therefore, there is an urgent need for government initiatives to create new policies. It is imperative to provide practical policies for the ocean energy industry, such as simplified administrative procedures.

Announced by the Korean government in 2017, the energy change roadmap provides extensive national energy policy changes, including phased reductions of nuclear power plants, the expansion of renewable energy and the promotion of regional industry. Figure 2 summarizes the "3020 plan for development of renewable energy" announced by the MOTIE. The objective of this plan is to obtain up to 20% of the nation's electricity supply, around installed capacity of 63.8 GW, from renewable energy by 2030 [9]. In addition, pursuing non-nuclear power sources, this policy promotes the development of eco-friendly, safe and efficient energy.

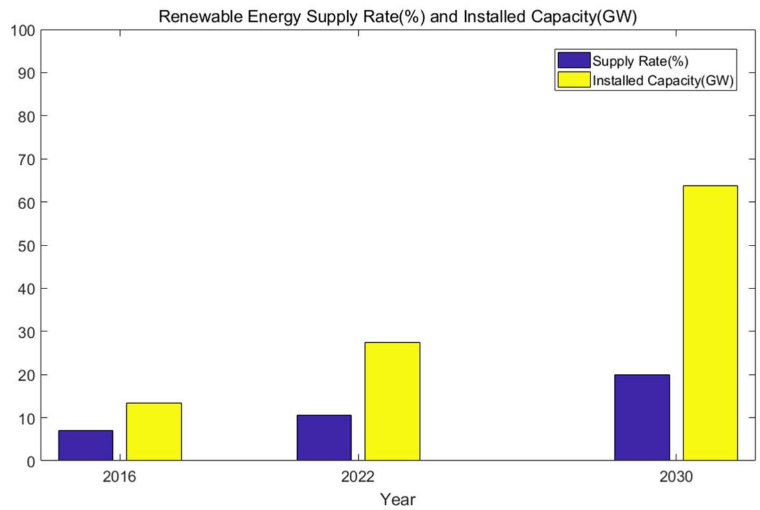

Figure 2. Renewable energy supply target in 3020 planning for renewable energy [9].

To achieve the goal of 63.8 GW renewable energy installed capacity, 48.78 GW of new facilities are required. More than 95% of the newly installed capacity is expected to be supplied by clean energy sources such as solar and wind power. The intention of this plan is to create a renewable energy system that will enhance the quality of life of its participants. The implementation plan includes expanding public participation, location determinations led by local government for development of renewable energy, large-scale project promotion, etc. The plan also intends to create a new energy industry to increase the existing energy industry competitiveness. However, this plan does not include any new or planned ocean energy facilities.

Figure 3 presents The Strategic Plan for Development and Support of New and Renewable Energy such as Ocean Energy announced by the Ministry of Oceans and Fisheries (MOF) in 2017. The MOF plan includes a 2030 Development Plan for Ocean Energy. In addition, the MOF 2017 plan has four strategies and it is summarized as follows:

- Strategy 1: Expansion of R&D in ocean energy and establishment of real sea test bed.
- Strategy 2: Construction of large-scale ocean energy farm.
- Strategy 3: Enter the global market and expand domestic supply.
- Strategy 4: Establishment of certification system and strengthening of policy support.

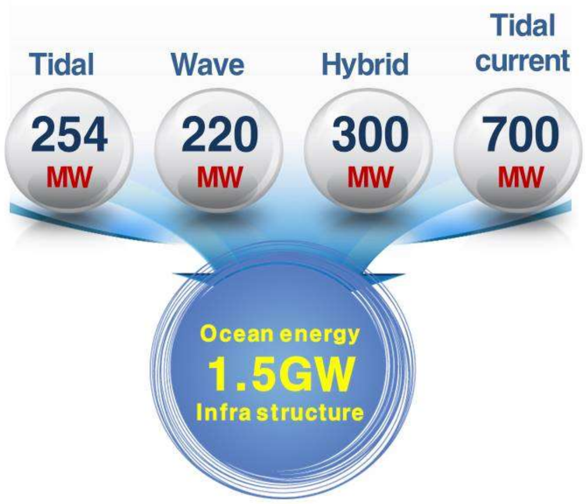

Figure 3. The target installed capacity of ocean energy by 2030 [10,11].

Strategy 1 is to expand the R&D in ocean energy and construct the sea test bed for wave and tidal current energy converters. Especially, certification system will be established to secure technical reliability and entry into overseas markets. This strategy includes the development of commercial level systems for MW class TEC. In case of strategy 2, it aims to establish the supply chain and the pilot array. The central government, local government and industry will jointly construct the large-scale ocean energy farms using tidal current, wave and wave-offshore winds. And then, the government will support that companies lead to construct the commercial scale ocean energy farms. The government will also support to establish the grid system and to increase incentives by adjusting REC (Renewable Energy Certificate) weights. Strategy 3 is to enter the global market for ocean energy plants and establish regular supply systems for ocean energy. In this strategy, Korea wants to supply more ocean energy to the home. And ocean thermal energy conversion power generation will be tested to secure track records. Strategy 4 is to establish the ocean energy certification system and the policy support. As shown in strategy, these strategies have the implication that the government will take the lead in securing the technological competitiveness in the world by raising the maturity of technology.

The MOF report analyzed the results and problems of ocean energy development and summarized the status of ocean energy resource development in Korea. The objective of the MOF plan is to construct a total of 1.5 GW of ocean energy infrastructure by 2030. It attempts to create new energy industries by fostering specialized ocean energy companies and constructing a supply chain. In addition, the target installed capacity of ocean energy infrastructure was established. The plan calls for the installation of up to 220 MW of wave energy, 300 MW of hybrid systems and 700 MW of tidal current energy by 2030. Meanwhile, tidal power will be maintained as 254 MW from the Sihwa Lake Tidal Power Plant without further capacity expansion because of environmental problems [10,11]. As government policy direction to provide clean energy is determined, ocean energy industry will grow. And sufficient investment and strategy considering the technical maturity will strengthen. However, in order to achieve these target capacities, active investment of the company is required. Not enough company participation is the biggest barrier to create a foundation for commercialization. These strategies include detailed plans, but there is a lack of ways to engage companies. Thus, it should induce company participation by establishing the national support strategy such as REC incentive. Only if these are satisfied, the policies can be more effective.

In case of tidal current energy, there are detailed plans for the development of large-scale tidal energy farms. As shown in Figure 4, first, the open sea test bed will be established by 2022 for performance test and evaluation of TEC. This will facilitate expanded research of tidal current energy and enable the establishment of a practical testing system. After the establishment of sea test bed, development of the commercial level system for TEC will be carried out. The goal is to develop the MW class TEC to establish the commercialization. Thus, the plan will promote technological development of tidal current energy in Korea. Additionally, Korea plans to construct a 10 MW pilot array in the southwestern sea of Korea using the MW class TEC. Finally, between 2026 and 2030, a 700 MW tidal current energy farm will be constructed around the southwestern sea of Korea.

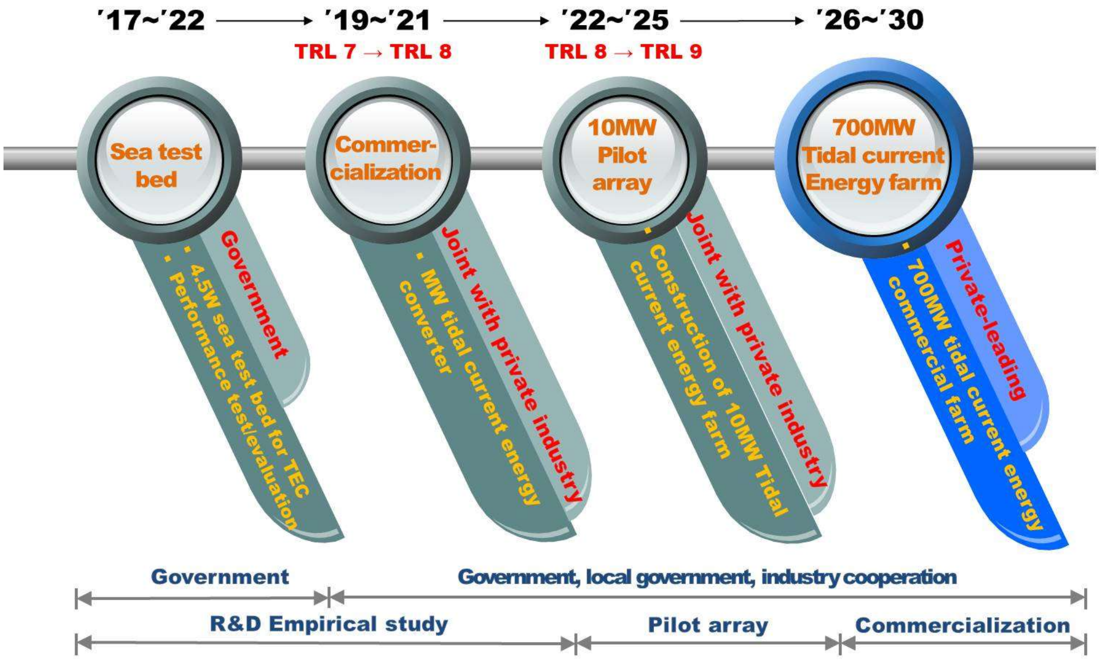

Figure 4. 2030 planning for the development of tidal current energy [10,11].

Furthermore, Korea must establish a systematic national strategy to create new marine industries and then secure its position as a global competitor in those industries. To this end, the MOF has announced a Basic Plan for the Marine Fisheries, Science and Technology Promotion [12]. This plan aims to create a rich and safe marine space. It has four strategies summarized as follows:

- Strategy 1: Promote marine fisheries, science and technology to create new industries and jobs. Specifically, cultivate the following five sectors because they are expected to be industrialized soon: ocean energy, ocean bio, marine equipment and robots, eco-friendly vessels and aquaculture.
- Strategy 2: Establish marine science and technology base to address and solve social problems.
- Strategy 3: Innovate a new research and development support system by the Korean government.
- Strategy 4: Create an ecosystem for sustainable development of marine fisheries, science and technology.

The development of ocean energy would enable meaningful advances in stabilizing Korea's power supply and reducing carbon emissions that contribute to the greenhouse effect. However, Korea should also consider the negative effects of ocean energy, such as marine environmental problems and ecosystem damage. The Marine Environmental Impact Assessment Act is designed to predict and evaluate the environmental impacts of the plans and projects that affect marine environments. The report assesses many environmental factors such as the site feasibility, the suitability of the plan and reducing methods for environmental impact [13,14]. The environmental impact assessment of ocean energy is conducted in consultation with the government. However, the aim and evaluation process are ambiguous at this moment. So verification of environmental impact and post-project environmental management processes must be enhanced. Especially, specific items and metrics will need to be classified according to project type, clearly.

There are many existing laws supporting the development of ocean energy. The Framework Act on Marine Fishery Development aims to help improve the national economy and the welfare of the people by establishing the government's agenda and policies for the rational management, conservation, development and utilization of Korea's marine resources and industries [15]. Since 2017, New Energy and Renewable Energy Development, Use, and Spread Promotion law has been implemented. One of these laws attempts to diversify energy sources by developing new and renewable energy technology and promoting the related industries. This law also aims to contribute to the preservation of the environment, sustainable development of the national economy and improvement of the welfare of the people by stabilizing the national energy supply and reducing greenhouse gas emissions [16]. The Energy Act, Framework Act on Low Carbon Green Growth and Rational Energy Utilization Act are also being implemented to support the development of new and renewable energy [17–19].

2.3. Market Incentive

To promote the new and renewable energy market, in 2012, Korea changed the Feed in Tariff (FIT) to the Renewable Energy Portfolio Standard (RPS) to provide Renewable Energy Certificate (REC). The RPS system is designed to provide a certain percentage of new and renewable energy from power companies with capacities equal to or greater than 500 MW, based on new energy development and the Act on the Development, Utilization and Supply Promotion of Renewable Energy. The obligatory supply rate of new and renewable energy will increase each year. As of 2019, the supply rate is 6.0%. After 2022, the obligatory supply rate will increase to more than 10% [16].

The market incentive plan, known as tradeable REC, supplements the RPS policy. The certificate verifies that the electricity was produced and supplied by new and renewable energy resources. Electricity production from a renewable energy facility is multiplied by REC weight and a REC certificate is issued on the basis of MWh units. Energy suppliers can purchase a REC if unable to achieve the obligatory new and renewable energy supply rate. The current REC weights are 2.0 for tidal current, 1.0 for tidal barrage with embankment and 2.0 for tidal barrage without embankment as shown in Table 1. The REC weights for wave and thermal ocean energy are not determined yet. The MOF is currently conducting research to adjust the REC weights for the tidal power and tidal current energy and to set new REC weights for Wave Energy Conversion (WEC) and Ocean Thermal Energy Conversion (OTEC) in an effort to induce active participation in the ocean energy development by private companies.

Table 1. REC certificate weights according to energy resources in Korea [16].

	REC Weight	Criterion	
		Type	Detail
Energy Resource	1.0	Hydroelectric power, Tidal power (with sea wall)	
	2.0	Tidal power (no sea wall), Tidal current energy	Fixed type
	1.0~2.5	Tidal power (no sea wall)	Variable type
	2.0 2.5 3.0 3.5	Offshore wind (according to grid connection distance)	≤5 km >5 km and ≤10 km >10 km and ≤15 km ≥15 km
	4.5 4.0	Energy Storage System(ESS) (with wind power)	In 2018, 2019 In 2020

Regarding funding, the MOF and the MOTIE provide public funding for ocean energy research and development (R&D) and demonstration projects. Together, the ministries have invested a total of 200 million USD in ocean energy technology development projects between 2000 and 2017. The MOF funding primarily focuses on open sea demonstrations through the "Practical Ocean Energy Technology Development Programme"; while the MOTIE primarily supports R&D projects through the "New and Renewable Technology Development Programme" [20].

3. Technology Status of TEC

The rotation of the Earth on its axis creates strong centrifugal forces. Tides are generated by the combined effects of the Earth's rotation within the gravitational fields of the Moon and the Sun. The principal and most apparent variations in tidal currents are caused by the relative positions of the Sun and the Moon. TEC is designed to extract energy from the kinetic energy of tidal currents caused by the rise and fall of the tides.

The southwestern sea of Korea is one of the most promising candidate sites for the development of tidal current energy. There are strong tidal currents above 4 m/s between islands. The Uldolmok and Jangjuk Strait possess abundant tidal current energy resources.

Figure 5 shows the status of research on tidal current energy conducted by the Korea Institute of Ocean Science and Technology (KIOST). As shown in Figure 5, KIOST has researched the commercialization of tidal current energy since 2001 and is now developing a 200 kW TEC. In 2022, KIOST plans to establish the 10MW tidal current energy farm.

3.1. Uldolmok Tidal Current Power Pilot Plant

The southwestern sea of Korea contains a group of islands called an archipelago. Because strong tidal currents often flow through straits, the archipelago's many straits are advantageous for the development of tidal current energy. Figure 6 maps the locations of the Uldolmok and Jang-Juk Strait, which are particularly attractive owing to their energy densities. According to earlier studies, the annual energy density of the Uldolmok Strait is 52.1 MWh/m^2 and the Jang-Juk Strait is 6.9 MWh/m^2 [21–23].

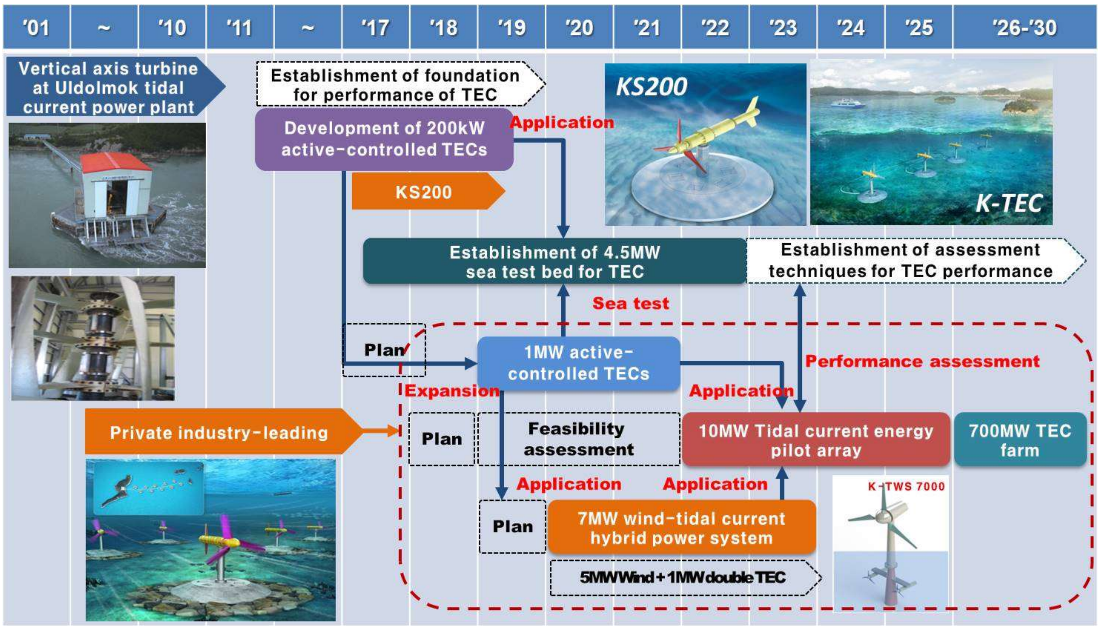

Figure 5. Timeline for tidal current energy research performed by the KIOST.

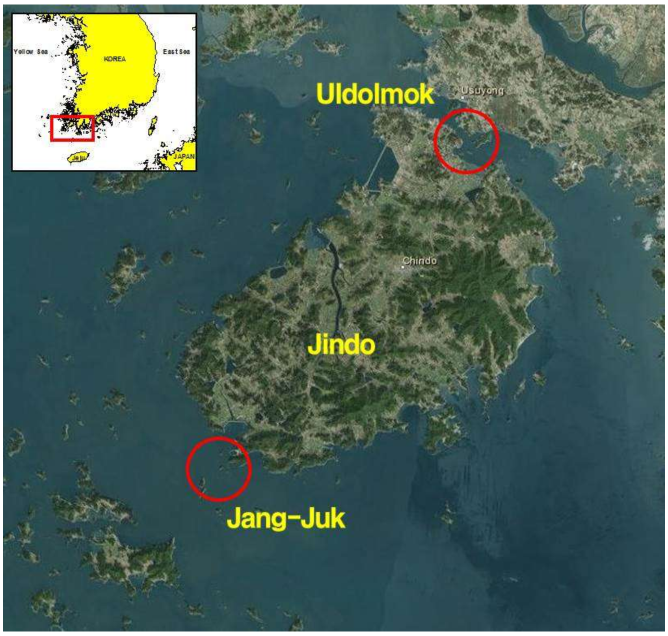

Figure 6. A Map showing locations of Uldolmok and Jang-Juk Straits.

Since 2001, KIOST has researched tidal current energy. In the course of this research, KIOST constructed the Uldolmok Tidal Current Power Pilot Plant which has an installed capacity of 1 MW. Figure 7 is a photo of the Uldolmok Tidal Current Power Pilot Plant, which is located at Uldolmok, Jindo, Korea.

Figure 7. A photo of the Uldolmok Tidal Current Power Pilot Plant.

The Uldolmok Tidal Current Power Pilot Plant currently produces tidal current energy using the vertical axis turbines. The plant functions as a sea test facility for tidal current energy. The support structure is the jacket type and measures 50 m tall, 36 m long and 16 m wide with a total weight of 1360 tons. As it was installed in a region where strong currents flow, many challenges were encountered during construction. Nevertheless, the power plant was built using only Korean technology and has since received considerable international attention [24].

3.2. Active-Controlled TEC

An active-controlled TEC is currently under development. The project aims to develop, validate, and suggest a standard model for an efficient and wide scope applicable TEC that actively manages variations in tidal current speeds and directions while controlling flow amounts. The project develops and demonstrates an active-controlled, 200 kW class TEC that achieves high efficiency, low cost and an operating capacity applicable for shallow sea conditions of approximately 20 m. Specifically, the project targets the following benchmarks: greater than 200 kW rated power in 2 m/s flow speed with system efficiency greater than 25% and a capacity factor of 30% or more. Additionally, the project developed a substructure design and construction techniques that reduce construction and maintenance costs.

To accomplish this, KIOST completed the open sea test of a 20 kW prototype model in 2015. The test achieved system efficiency of approximately 35% and a 2.93 kW power output in 1.5 m/s flow conditions. Based on the prototype model, KIOST began developing the 200 kW TEC.

The support structure is the part of TEC that consists of the tower, substructure and foundation [25]. For this project, the caisson-type gravity-based support structure was selected owing to factors associated with installation and maintenance. It was designed, fabricated and deployed by Hyundai Engineering and Construction Co., Ltd., which is located in Seoul, Korea, in 2016. The foundation width is 15 m in diameter, the height of the tower is 9.5 m and a total of weight is 350 tons. Figure 8 shows the support structure of a 200 kW TEC on the Myeongnyang vessel specially launched by Hyundai Engineering and Construction Co., Ltd.

Figure 8. The caisson-type gravity-based support structure.

In 2017, the performance of the Permanent Magnet Synchronous Generators (PMSG) and the main Drivetrain were evaluated using a portable dynamo test facility. The internal communication system and the active rudder device for automatic and passive yaw control have been also tested in indoor and underwater environments, as shown in Figure 9. The test report issued by Korea Electrotechnology Research Institute (KERI) found that generator efficiency was 89.5%.

Figure 9. Dynamo test pictures for PMSG and Drivetrain of 200 kW TEC.

Figure 10 features a photograph of the 200 kW TEC manufactured by KIOST in 2018. The 200 kW active-controlled TEC has been assembled and scenario test plan is being prepared. Additional works to confirm the yaw and pitch system are currently being conducted at the EK heavy industry company. The 200 kW TEC will be installed in the Uldolmok test site for open sea testing in the middle of 2019. This system helps accumulate track records to facilitate the commercialization of tidal current energy.

Figure 10. A photo of 200 kW active-controlled TEC.

3.3. Tidal Current and Pumped Storage Hybrid Power Generation

In Korea, various types of hybrid power generation systems are being researched to extend the applicability. The tidal current and pumped storage hybrid power generation system is one such system. This project aims to develop a tidal current and pumped storage hybrid power generation system, which combines with the dual flapping type system as a tidal current generator. The flapping type tidal current generator in the changed power transmission of the vertical arrangement can be applied to pump seawater through its mechanical power, which is a new concept in hybrid power generation. The principle is to pull sea water up into the storage tank using a flapping-type tidal current turbine and then allow the water to flow back into the sea through a pipe. In addition, control of each component of the hybrid power generation system is very important to improve efficiency. Control system is necessary to maximize power, detected faulty components and reduce loads. It can also contribute to increase the operation, maintenance and economic feasibility [26]. Figure 11 depicts the different head that this system uses to generate power by the previously described method.

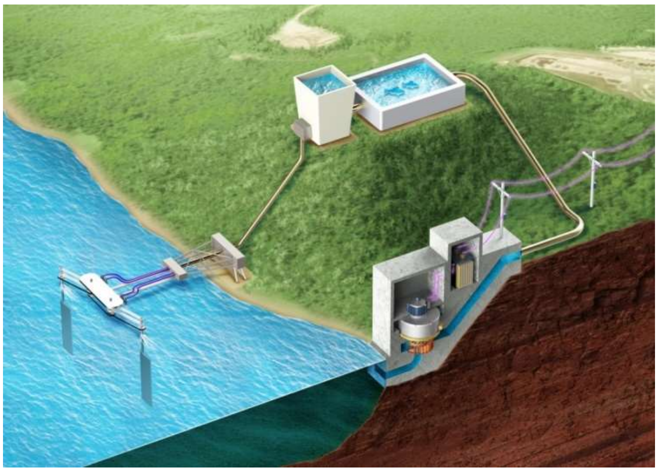

Figure 11. Schematic of the tidal current and pumped storage hybrid power generation system.

The project is funded by the New & Renewable Energy R&D Program of the Korea Institute of Energy Technology Evaluation and Planning (KETEP) grant and MOTIE. The main research focal points of this project are as follows:

(1) The development of design technology for the tidal current and pumped storage hybrid power generation system.
(2) The execution of indoor and outdoor experiments for the tidal current-pumped storage hybrid power generation system with an emphasis on demonstrating the feasibility of using the storage tank for aquaculture.

4. Open Sea Test Bed for TEC

Since 2017, the MOF has supported construction projects for open sea test sites for TEC. In the southwestern sea of Korea, the 4.5 MW sea test bed known as the Korea Tidal Current Energy Center (K-TEC) is being constructed for TEC in Jindo. The project for an open sea test bed with 5 berths of 4.5 MW grid-connected capacity for the tidal energy converters is scheduled from April 2017 to December 2022 by KIOST.

The main purpose of the TEC sea test bed is to construct an open sea test bed for performance evaluation of tidal current power generation system and facilities. This project includes the construction of sea test bed equipped with grid-connected systems and test facilities for performance evaluation of tidal current power generation components and factors such as power, load, blade strength, and non-destructive inspection, as shown in Figure 12.

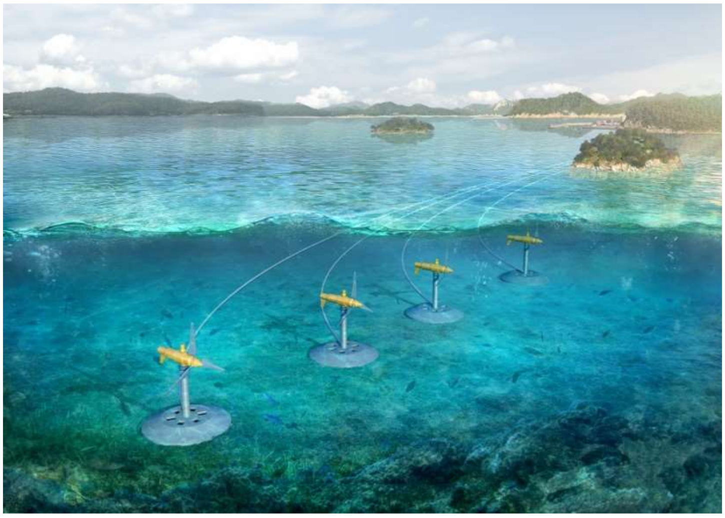

Figure 12. Open sea test site for TEC.

The tidal current test facility, K-TEC is to be built on two possible sites around Jindo, the Uldolmok and Jang-Juk Straits, which are shown in Figure 6. Submarine cables will be connected the offshore test site to enable power performance measurements. The test site consists of four 1 MW test berths and an 0.5 MW test berth. Five submarine cables from berths will be connected to the onshore substation and the grid system with the allowance capacity of 4.5 MW. Four test berths will be installed at Jang-Juk Strait and another test berth will be constructed at Uldolmok. Only submarine cables will be provided, and developers will have to install the TEC themselves. Relative to other sites, the greater depth and width of the Jang-Juk Strait make it a superior candidate for the construction of a large-scale tidal current energy farm.

The water depth of Uldolmok ranges from 20 to 32 m below the datum level. The peak tidal current speed rises to over 4 m/s in the ebb tide. The tidal range is up to 4.5 m in the spring tides and about 2.5 m in the neap tides. Whereas, the peak tidal current speeds of Jang-Juk Strait ranged from 3.34 to 4.22 m/s in the flood tides, with water depths approximately 21 to 35 m below the datum levels [27].

An onshore test field is defined as test facilities equipped with performance test facilities for components such as blade. There are plans to install testing facilities for blade strength, and non-destructive testing. Furthermore, K-TEC will be accredited by the Korea Laboratory Accreditation Scheme (KOLAS) in accordance with the national standards for blade strength, non-destructive testing, load and power performance. A design of the onshore test field is currently under way. Finally, KIOST will use this project to establish the infrastructure for technology standardization and promote the tidal current energy industry.

5. Conclusions

Energy policy is an important factor in determining energy demand and energy mix. Policy supplementation for subsidy dependence, private company participation and the creation of this new energy industry are needed to strengthen the ocean energy industry. To this end, this paper reviewed the current status of Korea's policy and technology of tidal current energy. Recent policy changes contribute to an optimistic outlook for renewable energy. However, there are many challenges to overcome in developing ocean energy, such as policy uncertainties, non-economic barriers and grid integration. The biggest challenges are as follows:

(1) Uncertainty of consent and low public acceptance In case of Korea, developers have to gain consents such as environmental assessment, use of public water and maritime traffic safety assessment from local governments or the central government. Approval is not easily obtained because the public acceptance is low in Korea. Therefore, it is necessary to develop ocean energy using bottom-up approaches such as the participation of local residents or local government. Moreover, the consent procedure must be simplified and suggestions for cultivating coexistence with existing users of project sites, such as fisheries and tourism.

(2) Marine environmental impact assessment for ocean energy development project To develop ocean energy projects, it is necessary to review and evaluate the project through an environmental impact assessment. However, the environmental impact assessment items are not specific and there are no items that focus on different types of project. The inability to verify mitigation methods presents another challenge. It is also necessary to systematize a post-construction monitoring and maintenance plans. Finally, the efficacy of the evaluation system must be strengthened by identifying and incorporating specific and important items for environmental impact assessments.

(3) Establishment of the supply chain system To promote ocean energy industrialization, it is essential to establish a supply chain system. Although options are limited for promoting the ocean energy industry, a cluster would enhance the industrial structure and the competitiveness of participating enterprises. Unfortunately, there are many difficulties in establishing a supply chain in the early stages of technology due to the absence of ocean energy industry infrastructure. Therefore, during the early stages, it is necessary to bolster market potential through R&D activities and by establishing the infrastructure. After that, the creation of the ocean energy industry must be induced by integrating related companies through the establishment of a pilot array in the medium term. This would then encourage the participation of private companies and thus facilitate the establishment of a supply chain through the construction of large-scale power generation farms. Moreover, it is judged that strategies such as securing REC weights must also be strengthened to secure further investment by private companies.

(4) Technical standards and certification for ocean energy The International Electrotechnical Commission (IEC)'s technical committee (TC) 114 (IEC TC-114) has published the 62,600 series of Technical Specification (TS) for ocean energy so as to support risk minimization and secure the reliability and stability of ocean energy converters. An open sea test bed for tidal current energy converters, which is under construction, will enable performance testing and evaluation. Additionally, a certification system would help dissolve trade barriers between countries and induce entry into overseas markets.

Dispersed generation supply would be stimulated by the expansion of ocean energy. It is crucial to both develop the ocean energy industry as a major player in the energy sector to enable eco-friendly and efficient energy and to leverage the new industry a new growth engine to stimulate private entrepreneurship, attract investment and create new jobs. Thus, Korea could promote a national ocean energy industry by actively utilizing it as an opportunity to foster new industry while and by the expansion of ocean energy supply. The new technology created in the on-going fourth industrial revolution could also be integrated into dispersed generation to further facilitate the creation of new ocean energy industries.

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Nomenclature

FIT	Feed in Tariff
IEA	International Energy Agency
IEC	International Electrotechnical Commission
KERI	Korea Electrotechnology Research Institute
KETEP	Korea Institute of Energy Technology Evaluation and Planning
KIOST	Korea Institute of Ocean Science and Technology
KOLAS	Korea Laboratory Accreditation Scheme
K-TEC	Korea Tidal Current Energy Center
MOF	Ministry of Oceans and Fisheries
MOTIE	Ministry of Trade, Industry and Energy
OTEC	Ocean Thermal Energy Conversion
PMSG	Permanent Magnet Synchronous Generators
REC	Renewable Energy Certificate
RPS	Renewable Energy Portfolio Standard
TEC	Tidal Current Energy Converters
TC	Technical Committee
TRL	Technology Readiness Levels
WEC	Wave Energy Conversion

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