A Study on the Compensation System for Hydro power in Response to Climate Change

By

CHUNG, Hoon

CAPSTONE PROJECT

Submitted to

KDI School of Public Policy and Management

In Partial Fulfillment of the Requirements

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ABSTRACT

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Korea's electric Power wholesale market, introduced in 2001, is a CBP market that reflects the variable costs of each power plant. The purpose of this market is to increase the efficiency of electric power generation and reduce the cost burden of customers by inducing the reduction of electric power production costs. But Korea's power market is a de facto monopoly dominated by excessive interference from the Ministry of Trade, Industry and Energy and KEPCO.

The main sources of power plants of KEPCO's subsidiaries are nuclear or coal, which are at high risk of accidents and are pointed out as the main reason of air pollution and greenhouse gases. However, under the CBP system, the operation rate of these plants is high but the operation rate of LNG complex power plants, which has relatively low greenhouse gas emissions, is low. This is only because current CBP market focuses on economic factors such as fuel costs. In addition, very small compensation for hydro power plants, which is clean energy, is hindering the development of new hydro power plants.

Therefore, this study focused on promoting the introduction of hydro power plants in response to climate change. The system improvement was proposed to promote new introduction of hydro power plants by analyzing problems of the current system, adding new elements of settlement, and improving the existing settlement formula.

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1. Introduction

In November 2016, the Paris Agreement of the United Nations Framework Convention on Climate Change (UNFCCC) was adopted in Paris, France, a new binding climate agreement was born. Accordingly, the Korean government established the "8th Basic Plan for Electricity Supply and Demand" in 2017 for a sharp increase in eco-friendly energy with the focus on new renewable energy as well as phase-out of nuclear and coal-fired power plants. The government also proposed a blueprint to supply 20% of the domestic electric power demand with new-renewable energy by 2030 through the "New and Renewable Energy 3020" policy.

Korea's electric power market is a monopolistic market. Although the electric power generation sector itself has a competitive system, the transmission and distribution sectors ~~is~~ are monopolized by Korea Electric Power Corporation (KEPCO). In order to enhance efficiency through competition in electric power production and supply, a reform was carried out in 2001 in the name of "restructuring of the electricity market structure". The main goal of the reform was to separate six power generation companies and Korea Power Exchange (KPK), independent of KEPCO and eventually to remove KEPCO's monopolistic position in the electric power market. In other words, the reform focused on enhancing effectiveness of electric power supply under the demand and supply system. To improve efficiency, all electric power should be transacted by the System Marginal Price (SMP), based on the "supply and demand" in electric power market, rather than the Feed in Tariff (FIT) system, in which power transactions are made with KEPCO by deciding the unit cost of electric power production in advance. The SMP system is efficient in terms of electric power supply-as the power generator can be operated only when the cost of fuel is reduced to secure competitiveness, which ~~is~~ makes it fundamentally different from the FIT system.

However, this separation attempt was not successful. According to the Electric Power Statistics Information System (EPSIS) operated by KPX, almost 70% of electric power was still provided by 6 big power generation KEPCO subsidiaries, and the remaining 30% of electric power was provided by other 1,800 companies in 2017. This shows that despite the separation, KEPCO's cartel was still powerful, and their monopolistic status remained unchanged.

The most important factor in determining the SMP is the fuel cost, but the SMP system raises barriers for LNG power plants to enter the market due to the high fuel cost, regardless of their low-carbon and low-dioxide. On the other hand, the constructions of nuclear and coal-fired power plants are promoted as they have relatively lower fuel cost. In addition, in the case of hydro power plants, they are in the deficit due to the insufficient precipitation since they are heavily dependent on rainfall for their fuel power. These are negative side effects of the SMP system, which are strictly based on fuel costs: economic logic. Although the Korean government attempted to compensate these problems by adding the Fuel Switching Factor (FSF), an eco-friendly compensation factor, to the CP (Capacity Payment), a compensation system for the recovery of fixed costs (mainly construction cost), in 2016, yet the prevailing opinion among electric power market experts was that the FSF is still not sufficient enough. Another concern of the FSF is that it does not fully reflect the environmental aspects as 80% of the FSF evaluates the contribution of generation amount and only 20% of FSF evaluates the contribution of environmental aspect.

Hydro power represents eco-friendly energy not only in Korea, but it is a forerunner of energy power in the world. [Talk about the significance of hydro power]. With the sufficient development potential of hydro power, construction of nuclear and fossil fuel generators should be avoided. As times change, so should energy policies. Just as hydro power plants, t should encourage and support eco-friendly energy, rather than power plants that cause pollution and further risks. Therefore, this report will study the side effects of the Korean government's strong intervention in the energy market and devise solutions to draw up the government's support policies and improvement measures for hydro power. As this will attempt to propose best ways to actively respond to climate change, it is strongly recommended that this report is reviewed with a keen interest by the Ministry of Trade, Industry and Energy, KEPCO, and KPX.

The structure of this report will be as follows: Firstly, introduction of previous studies about hydro power will be covered as well as Korea’s current situation and problems of the electric power market. In the next part, this report will investigate the compensation system of the U.S. market, which is considered to be the most advanced electric power market, and utilize it to draw out the optimal compensation measures for Korea’s electric power market.

2. Review of Literature

2.1 Advantages of hydro power

Hydro power not only has an advantage in terms of the electric power grid system, but also contributes to maintaining a smooth society. The following two previous reports describe the advantages of hydro power in aspects of the electric power grid system, society, and climate change.

2.1.1 K-water. (2016*). A Study on the Revitalization of Renewable Energy Business.*

According to this report, hydro power has following 5 advantages in terms of the electric power grid system. First of all, Hydro power quickly reacts to changes in electric power demand. Compared to nuclear and coal-fired power generators, hydro power can be rapidly increased when there is sudden increase in the demand for electric power hence the ability to respond to sensitive demand changes. In particular, from the start-up time perspective, hydro power can operate in less than 10 minutes, as opposed to nuclear and thermal power generation that require much more start-up time. Second, hydro power can supply stable electric power. Since hydro power uses a head and pressure difference of water, rather than external power sources, hydro power can be generated during blackouts in a country, minimizing risks by supplying electric power to other nearby power plants. Third, hydro power has high energy conversion efficiency. The efficiency of hydro power generator, of which efficiency is between 80-90%, is significantly higher than that of thermal power generators (between 40-50%). Fourth, hydro power has stability and eco-friendliness–with much less accident risks, comparing to nuclear power and minimal greenhouse gas emissions unlike coal-fired and LNG power plants. Finally, hydro power has the potential as distributed electric power. Hydro power (especially small or micro hydro power) is highly valuable as a distributed resource in response to the regional energy demand in terms of the operation of the electric power grid system. Based on these advantages of hydro power, this report argues that the introduction of hydro power should be expanded and the contribution to hydro power should be compensated.

2.1.2 DNV•GL. (2015*). The hydropower sector's contribution to a sustainable and prosperous Europe.*

This report analyzes the following advantages of hydro power in aspects of society and climate change. First, hydro power can generate constant production of new values. As of

2015, the value of hydro power is 38 billion euros, and the expectation is that it will grow up to 75 to 90 billion euros by 2030. This means that the value added derived from hydro power will continue to increase. Second, hydro power can bring brisk investment. In fact, European hydro power manufacturers have invested an average of 8 to 12 billion euros a year, and their planned investment by 2030 has been on a steady rise to 180 billion euros. Third, hydro power provides various job opportunities. It was found that hydro power business has direct and indirect effect on job security of more than 100,000 jobs, and each full-time worker in the hydro power sector produces an approximately average annual value of 650,000 euros. This is eight times the average value of Europe's manufacturing sector. Fourth, the tax from the hydro power sector in Europe is the main income of its budget. Contribution of direct taxes is estimated at around 15 billion euros a year, which is several times more than the limited amount of subsidies for fostering hydro power generation. The tax from hydro power is poured directly into the budget to boost the social community, creating a virtuous circle. Finally, the paper maintains that the European government can add an annual economic value of between 10 and 20 billion euros (excluding the potential value of flood prevention) by promoting tourism and sailing, including irrigation and industrial waters as well as drinking water and flood control.

Furthermore, hydro power functions as an important factor in the climate change policy. Under the 2030 Climate Change Policy, the creation of an appropriate, safe and sustainable energy system–with legally-binding targets, would be an important part of the policy, and three key objectives are presented for this purpose. The first is sustainability. In other words, it looks at whether clean and safe energy can continuously promote human prosperity. The second is security of supply. This points out the ability to contribute directly to the maintenance of stable electric power grid systems by providing mobility and reliable capacity for immediate operation when needed. The report argues that hydro power should be expanded for the permanence of mankind in the future as it perfectly conforms to the three aforementioned objectives of the European power system.

When assessing the value of hydro power, investigation of the public awareness toward hydro power would be a good way. The following report evaluated the value of hydro power generation by utilizing the Contingent Valuation Method (CVM) and conjoint analysis, based on survey, which are representative characteristic techniques of the Reveal Preference Method (RPM).

2.1.3 K-water. (2014). *Comparison of hydro electronic power with other power source in terms of environmental cost.*

This report analyzed the value of hydro power as an alternative to solving increasingly crucial environmental problems. It points out that the current production and supply of electric power are causing many social costs, such as environmental damage to nature, and that social costs are overlooked under the current SMP system, which only focuses on the cost of production. Thus, the Contingent Valuation Method was applied and, it was further analyzed that environmental value from hydro power is 40~60 won/kWh compared to other electric power sources. This means people's extra willingness to pay (WTP) is at 40~60 won/kWh when using hydro power-produced electric. Furthermore, the results of calculating environmental costs by applying the Cost Assessment of Sustainable Energy System (CASES) show that hydro power cost is the lowest. In addition, the survey found that nuclear power and coal-fired power costs were 2.8 times and 34-44 times higher than hydro power (excluding social damage and handling costs when if there are accidents) respectively.

Consequently, it was concluded that the price of electric power should be determined by reflecting these environmental costs, and that a legal basis should be established in order to compensate the appropriate price of hydro power.

2.2 Problems of current CBP system

Despite the various merits of hydro power and the positive public perception, Korea's electric power market system poses many problems. The following paper describes the issues of Korea’s system.

2.2.1 K-water. (2013). *A Study on the adaptation of the electric power generation business according to the change of electric power market.*

This report argues that there are many problems in the current Cost Based Pool (CBP) market, recognizing its malformed structure due to the discontinuation of Reconstruction of Electric Power Industry.

The first is a dualized generation plan. Korea’s electric power market currently has a divided generation plan system that undermines the efficiency of the CBP market due to its ‘price-setting generation plan’ and ‘operation generation plan’. In other words, a hypothetical plan called ‘price-setting generation plan’ reduces the power purchase cost of KPX by setting SMP as low as possible, and ‘operation generation plan’, which operates actual electric power market, is established in consideration of electric power transmission congestion and various constraints. The separation of the price-setting mechanism and the actual market-operated mechanism prevents the efficiency and price of the electric power market from being linked, and it eventually comes to a point where it provides distorted price signals to the market. Second is the price issue by region. Wholesale prices should go up in the areas where electric power transmission losses are large or where electric power generation facilities are insufficient. Wholesale prices fall in the areas with low transmission losses due to the nearness of large loads or where electric power generation facilities are sufficient. This is a natural price signal of the electric power market. However, the current regional coordination coefficients do not fully reflect these signals. Third is power generation pump-up. Under the current CBP system, the ‘centralized power generators’ are being bid for the actual capacity available by time, but pumping-up power generators are leading SMP to fall by bidding for the total planned amount of electric power generation through the transaction day by time after forecasting of SMP. This is a typical case, where a government distorts price signals by directly interfering with SMP when it must be determined by supply and demand. Finally, there is a problem of the determination of power generation costs. SMP is basically calculated by fuel cost. However, there are some time differences between the time of fuel purchase and the time of the data reflected for operation of the electric power market by the ‘committee of cost evaluation’. So changes of the fuel cost in the electric power market are not immediately reflected.

In addition with the exception of SMPs, Capacity Payment (CP) and Auxiliary Service Payment (ASP) are the main compensation systems in the electric power wholesale market. Yet, it remains problematic since compensation under the distorted SMP is not adequately compensated by CP and ASP. To solve these problems, the report argues that the environmental costs, fuel-related auxiliary costs and maintenance cost should be added.

2.3 Potential of hydro power in Korea

Many argue that Korea has no terrain suitable for hydro power. However, Korea's hydro power potential is abundant. The following report talks about developing potential of hydro power.

2.3.1 Korea New Renewable Energy Association. (KNREA, 2019). *A Study on the comprehensive development plan of small hydro power project in Korea*

The report presents the current status of Korea's small hydro power development, the capacity for future development, and comprehensive alternatives for revitalizing hydro power generation. Currently, the future of small hydro power development is uncertain due to a drop in profitability caused by the low SMP and Renewable Energy Certificate (REG) prices. The findings, however, showed that Korea's potential for developing small hydro power plants is around 6,500 MW, which means it has the potential of 6.5 units of 1,000 MW-class nuclear and coal-fired power plants. Therefore, in order to promote small hydro power generation, four measures are proposed: introducing an incentive system and rationalized management, strengthening administrative services for new and renewable energy, developing new business models, and enhancing the acceptability of residents. In particular, the argument that Renewable Energy Portfolio Standard (RPS) weighs for new facilities should be paid differently, based on capacity, and that reconstructed small hydro power plants should be benefitted by the RPS system, are considered to have considerable validity.

3. Structure of the domestic electric power market

3.1. Overall market structure and the SMP system

KPX operates and manages the electric power market and is in charge of selling electric power purchased from suppliers (electric power generation companies) to KEPCO. At the same time, KEPCO is in charge of transmission and distribution of electric power purchased from KPX to the customers. In other words, KPX is a wholesaler, and KEPCO is a retailer. The basis of the existence of the electric power market is the 'Electricity Business Law'. As the law stipulates the 'electric power market operation rule', the rules set out all tasks related to the electric power wholesale market, such as power generation, power market operation and settlement while power generation companies and KPX operate within the boundaries of the regulations.

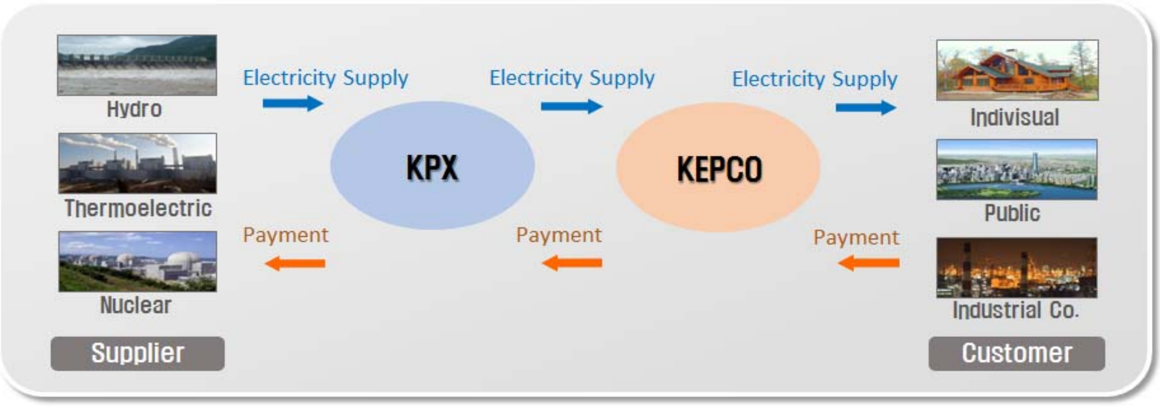

Figure 3-1 : Korea's electric power market structure

* The compensation money given by KPX transfers to the electric power supplier: **SMP**

Previously, the electric power price was negotiated with KEPCO in advance, considering the operating cost as well as the costs of capital of each power plant. However, this turned out to be an inefficient way for electric power generation companies. Although they did not make effort to reduce the costs, all of the costs were paid back to them as the price was already negotiated with KEPCO. However, in the newly introduced electric power market (2001), SMP is determined by demand and supply of electric power, and each electric power generation company has to compete in order to obtain the right to operate the generator. SMP is determined at the point of intersection with demand and electric power generation companies' "supply bidding" (predicted a day before), and 24 SMPs are determined hourly every day. SMP is determined by the principle of minimizing the cost of the generators in the supply bidding. Each electric power generation company has to determine operation status and generator's hourly output through supply bidding, of which the highest generator's cost for electric power generation satisfying the demand will be regarded as a "marginal price generator", and this "marginal price" will be determined by SMP at that time. The most important factor in determining SMP in Korea is fuel cost. More precisely, SMP consists of "variable cost", "start-up cost" and "no-load cost". Among these, the biggest factor determining SMP is variable cost, which the Korean government defines the only fuel cost.

As shown in Figure 3-2, it assumes that Korea's power generation capacity is approximately 100,000 MWh (= 100 million kWh). Another assumption is that all generators participate in the supply bidding. According to the principle of minimizing costs and the government policies, hydro generators and new-renewable generators are disposed at the bottom of "bidding stack" since they are regarded as if their fuel cost is zero, followed by nuclear power, coal and LNG gradually. If the 24 o'clock demand was 60,000 MW, as shown in the graph, LNG & oil generators are not needed. It is only needed up to #9 coal generator's operation which meets the demand, and if the operating cost of this #9 generator was 64won/kWh, it is determined at 24 o'clock SMP, and this will be applied to all generators.

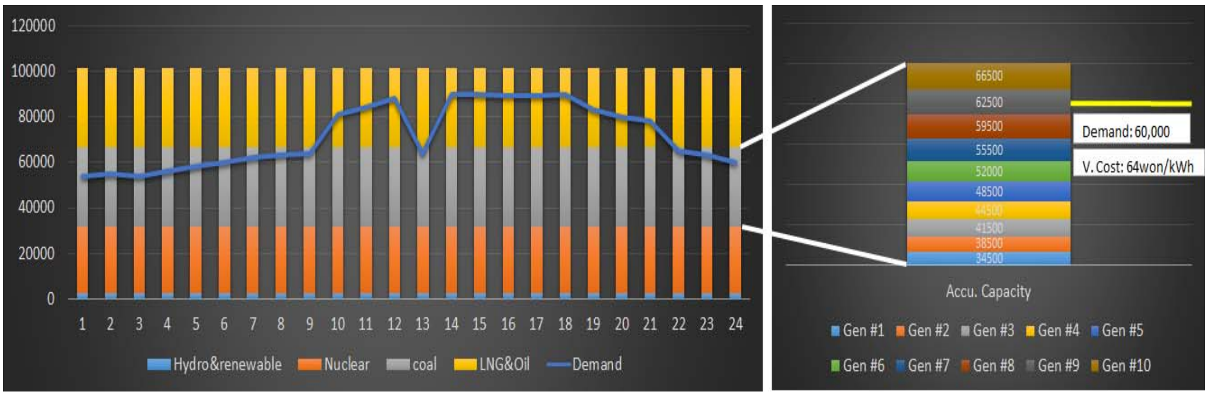

Figure 3-2 : Determination of SMP

This SMP decision-making system might be seen as a high-efficient system through competition among electric power generation companies. However, they pose following problems.

Firstly, the current SMP decision-making system causes serious profit differences by generation source. Suppose that “A” power plant is a nuclear power plant. Nuclear power plants are one of the cheapest fuel-cost generators. The initial fuel cost of the nuclear power plant was 5.84 won/kWh, but the SMP increased to 94.64 won/kWh in 2018. They make money 15 times more in simple calculation. Of course, the operating cost of the “A” power plant is not only the fuel cost but it also is needs different costs, such as the labor cost, repair cost, and so on. So the *actual* profit of the “A” power plant will be less than what is expected in simple calculation. Considering the fact that other power plants have more expensive fuel cost, it can be deduced that nuclear power plants have relative advantage under the SMP decision-making system. To prevent this problem, the Korean government introduced the "settlement adjustment factor", yet this is beyond the subject of this study and will not be discussed separately.

Secondly, the current SMP decision-making system induces the withdrawal of LNG complex power plant from the electric power market. The fuel cost of LNG complex is 97.87 won/kWh. Although the fuel cost of LNG complex power plant is higher than of coal power plant, it is highly responsive to demand and can have large capacity. It also has an advantage of less greenhouse gases and fine dust compared to coal power plant. Nevertheless, as shown in Table 3-1 below, the capacity of facilities is similar, but the volume of electric power trading is only 63% of coal power plant. This also shows that, due to the nature of the SMP decision-making system, the higher the fuel cost, the harder it is to be operated. Higher fuel cost makes it difficult to make such a high margin as nuclear power. In other words, the current SMP decision-making system is a deformed system that induces the withdrawal of LNG complex power plant from the electric power market which are more eco-friendly energy than coal. Instead, it allows the market entrance of coal power plant which emits more greenhouse gases and fine dust.

·Table 3-1 : Power generation by power source in 2018

(Unit : MW, GWh)

Sortation	Nuclear	Coal	Oil	LNG	Pumping Hydro	Others	Total
Capacity	21,850	36,899	4,319	37,834	4,700	13,490	119,092
Trade Vol.	127,078	229,350	6,537	144,067	3,899	26,105	537,035
Trade rat.	23.7%	42.7%	1.2%	26.8%	0.7%	4.9%	100.0%

Thirdly, linking the competitiveness of the power plant to fuel costs is a traditional idea. Almost all countries of the world are shifting to a drastic response system with various policies to counteract climate change. As one of the key policies tackling climate change is energy policy, and it should take into account a country's economy as well as the environment and sustainability. Comprehensive signals that reflect such factors should be provided to the electric power market. However, the current SMP system completely ignores the recovery cost of nuclear power plant accident, social cost of fine dust, and greenhouse gases caused by coal power plant operations.

Finally, it is easy to manipulate SMP by the government or public organizations. The most simple way to do so is tampering with the demand. KPX anticipates the demand and announces it a day earlier. For example, if KPX intentionally anticipates a low demand, the power plants with higher fuel cost will not be able to operate, thus SMP will decline since only the power plant with lower fuel cost will be operated. In this case, the value of the electric power wholesale market will decline. This means KPX needs less money to purchase electric power from electric power generation companies. Except for national blackout cases, KPX is free of responsibility for the failure to anticipating demand, hence no punitive regulations.

3.2. Composition and issues of the compensation system for suppling electric power

Power plants are divided into "central power plants" and "non-central power plants". Central power plants are those with a facility capacity over 20MW that receives generator-operating directions from KPX, and those under 20MW or do not get directions from KPX are classified as non-central power plants. The new renewable energy is generally classified as non-central power plants as they cannot get directions from KPX due to their natural feature. For example, Suppose KPX give an order to “B” solar power plant to operate for the lack of electricity, but if it is rainy day, “B” solar power plant cannot be operated.

The profit structure of the non-central power plants is simple. The revenue for suppling electric power is calculated by multiplying SMP to the amount of hourly electricity generation. In addition, the Korean government introduced the RPS system in 2012 for non-central power plants to compensate for the lack of revenue in case the SMP is not sufficient.

On the other hand, central power plants have a different profit structure. While they are not covered by the RPS system, the cost of construction and operation of the power plant are retrieved through the complex compensate system shown in Table 3-2.

Table 3-2 : Payment system for generating of electric power

Sortation		Description
SEP		Scheduled Energy Payment
CP		Capacity Payment = Energy(produced electric power) X RCP X RCF X TCF X FSF
CON / COFF		Constrained-On energy payment / Constrained-Off energy payment
ASP	SRP	Standing Reserve Payment
	RRP	Replacement Reserve Payment
	GFP	Governor Free Payment
	AGCP	Automatic Generation Control Payment
	BSP	Black Start Payment

To sum up, SEP is the calculated value of SMP using a specific formula (possible to consider this as SMP), and CP is the designed reward to recover the fixed cost, such as construction cost. Additionally, CON/COFF can be regarded as the reward for non-planned produce of electric power (CON) or forcing to stop producing electric power (COFF) in accordance with orders of KPX. Finally ASP is the reward for its contribution to stabilizing the electric power grid system.

The determining factors of CP are composed of reference capacity payment (RCP), reserve capacity factor (RCF), time of the day capacity coefficient (TCF), and fuel switching factor (FSF). ASP is composed of 5 factors: standing reserve payment (SRP), replacement reserve payment (RRP), governor free payment (GFP), automatic generation control payment (AGCP), and black start payment (BSP). However, CP entails many challenges as much as SMP.

Currently, RCP is set at 9.46 won/kW, yet this payment is continuously disputed. The electric power market experts argue that the current RCP level is too low to cover fixed costs, and they maintain that the government has to draw appropriate RCP level through public-private studies. However, the government does not allow it. In the early 2010s, the shortage of CP could be replaced by a high SMP during high oil prices, but since the mid-2010s, SMP has been low due to the oil price fall, hindering the development of hydro power and LNG power plants to the electric power market, along with low CP level.

RCF is a weighting element according to geographical location. RCF is designed to induce generators that are built near large consumer groups. Therefore, generators located close to large consumer groups or big cities would have high RCF level. Conversely, generators located far from such environment have low RCF level. This is because the closer the generator is to a large consumer group, the lower the cost of building electric power lines, and the less electric power loss. However, in the first half of 2019, RCF was 0.9277, which is equally applicable to all generators in Korea. In fact, it is currently a nominal weighting element, yet it is not certain whether RCF will function appropriately in near future.

TCF is a weighting element corresponding to the time of generation and is applied with a range of 0.384604 to 3.444007 based on the 2019 first-half weekday standard. In order to induce generation during daytime when the power demand and weight are high, but the weight is low at night and dawn when the power demand is low. Currently, TCF is considered to be a reasonable element reflecting the importance of peak generation, with sufficient amount of weight difference.

FSF is a fuel switching factor, a settlement element designed to benefit eco-friendly energy in 2016. However, a problem occurs in this situation. In FSF, the contribution degree of power generation is evaluated by 80%, compared to the 20% evaluation of the environmental factor. The contribution degree of power generation gives benefit to fundamental power plants, such as nuclear power and coal-fired power plants, which works against the peak power plants – hydro power and LNG power plants. Considering that the Ministry of Trade, Industry and Energy manages the electric power market along with their affiliated public corporation, KEPCO and its subsidiary power generation companies, it can be deduced that their main electric power sources are nuclear and coal-fired power. In other words, FSF is a deformed element that is hard to be sought around the world, combining the demands of an era of eco-friendly power generation with the greed of the Ministry of Trade, Industry and Energy. Of course, K-water's hydro power does not bring any disadvantages by inserting a clause, yet it is hard to deny that the design of the FSF itself is a problem.

So far, the components of CP are reviewed, and serious challenges are found to be present with RCP, RCF, and FSF, except for TCF. Nevertheless, considering the nature of the problems, people can realize that these do not come from its structure, but too much of the government interference might be the cause of the problems. In addition, CP is a method that is determined by the Cost Assessment Committee and not by demand and supply, unlike SMP. This implies that CP can be manipulated since it only discloses the results, rather than the process and the evidence data. Consequently, CP has been continuously modified in accordance with the intentions of the Ministry of Trade, Industry and Energy and KEPCO, and has had a huge impact on determining the profits of the electric power plant.

3.3. Problems of settlement adjustment coefficient

The settlement adjustment coefficient was first introduced in 2008 for the proper allocation of revenue between KEPCO and subsidiary companies in order to stabilize the electric power market wholesale price under the situation, in which the Korean government is controlling the market price. However, the settlement adjustment coefficient has been pointed out as a crucial concern because it makes difference in electric power wholesale price in line with its power source such as nuclear and coal. It also has been conflicting with the competitive market system of the electric power wholesale market, resulting in the inefficiency of investment in power generation facilities. The settlement adjustment coefficient is determined between from 0.0001 to 1. For example, if 'A' power plant's revenue is 10,000 won, and the settlement adjustment coefficient applied to the plant was 0.1: 'A' power plant's final revenue would be 1,000 won. However, these settlement adjustment coefficients can be manipulated at any time by the Ministry of Industry and Energy and KEPCO, corrupting a certain standard. If KEPCO is in deficit, but KEPCO's subsidiaries are in surplus, it is possible that KEPCO would take away the surplus by lowering the settlement adjustment coefficient to make up its deficit. In the case of hydro power plants, however, this potential situation is already found to be inadequate as the introduction of settlement adjustment coefficient was failed due to K-water's opposition.

4. Compensation policy of the U.S. in electric power production

4.1. Structure of the U.S. electric power market

In this paper, the U.S. market was analyzed by referring to Federal Energy Regulatory Commission (FERC), *Korean Power Industry Trends* (KPX, 2017) and K-water's research on *Ways to Revitalize Renewable Energy Businesses* (2016). Areas that operate THE electric power market in the U.S. are ISO-NE, NYISO, PJM, MISO, SPP, ERCOT and CAISO (see figure 4-1). The seven agencies account for more than two-thirds of the total U.S. electric power load and are required to purchase or sell electric power through wholesale electric power markets operated by either Indirect System Operators (ISO) or Regional Transmission Organizations (RTO). The electric power is traded mainly for bilateral contracts with existing power companies in the northwestern, southeastern and southwestern regions that do not have ISO or RTO. With the advent of ISO/RTO, the U.S.' electric power market shows two different types: 1) centralized market model and 2) a traditional regulatory model. Both are regulated by the federal government.

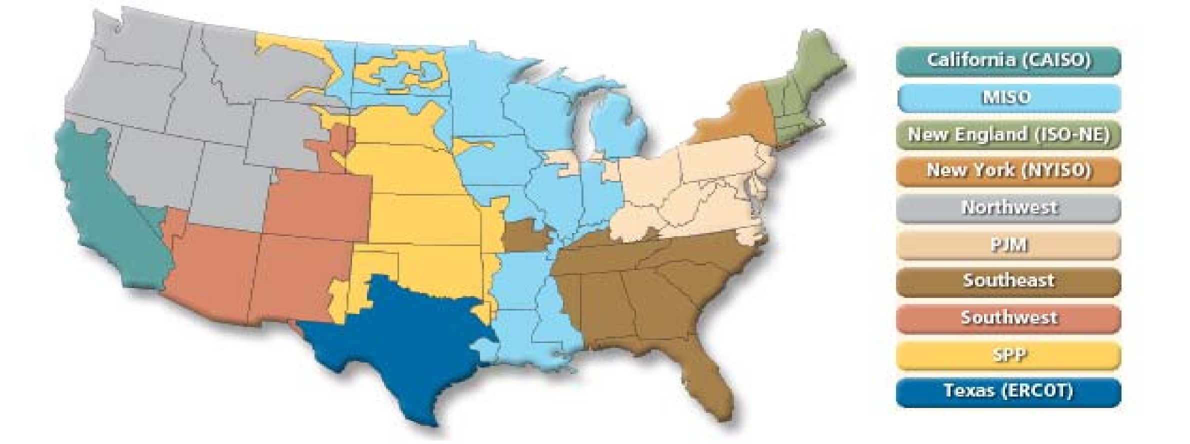

Figure 4-1 : Overview of the electric power market in U.S.

Table 4-1 : Status #1 of each jurisdiction in U.S.

Sortation		Established	Jurisdiction area
RTO	ISO-NE	1997	Connecticut, Maine, etc. (6 states)
	PJM	1997	Pennsylvania, New Jersey, etc. (14 states)
	MISO	1998	North Dakota, Missouri, etc. (15 states)
	SPP	2004	Arkansas, Minnesota, etc. (14 states)
ISO	NYISO	1999	New York
	CAISO	1998	California and some parts of Nevada
	ERCOT	1996	Texas

* Federal Energy Regulatory Commission (FERC) Electric Power Markets (www.ferc.gov)

* The jurisdiction and size of each of the seven regions are shown except for the areas that do not have ISO or RTO.

Table 4-2 summarizes the maximum electricity load and power generation facilities, annual power generation, total length of high-voltage transmission lines, and the market size for cross-check. As shown in Table 4-2, PJM's facility is the highest, followed by MISO and SPP. In addition, PJM also has the largest market size, followed by MISO and ERCOT.

Table 4-2 : Status #2 of each jurisdiction in U.S.

Sortation	PJM	MISO	ERCOT	CAISO	SPP	NYISO	ISO-NE
Max Load(MW)	165,000	127,000	69,000	47,000	46,000	34,000	28,000
Capacity(MW)	184,000	180,000	77,000	60,000	83,000	39,000	31,000
Production(TWh)	780-840	600-680	340-350	230-260	225-240	160-165	120-135
T. Length(Mile)	72,000	66,000	46,000	26,000	61,000	11,000	8,000
Market Size($M) (2014~2015)	50,000	32,500	15,000	12,100	10,600	14,700	10,600

* Wholesale Electricity Market Design Initiatives in the U.S. (EPRI, 2016).

Consequently, this report aims to derive a reasonable compensation method for the renewable energy by identifying power generation compensation system of PJM with a comparison to the domestic compensation system.

4.2 Characteristics of the PJM power market

4.2.1 Characteristics of the PJM electric power market and differences between Korea

The PJM power market is a pool system that incorporates power generation, transmission and distribution. Its main characteristics are stable long-term contracts among market participants, the ability optimize, the central control of the electric power generation, transmission, and distribution. The method of determining the electric power transaction price in PJM is Locational Marginal Pricing (LMP), which includes both the generation marginal cost, calculated by considering geographical specificity and the energy supply cost of the area that has caused congestion in the grid. LMP consists of system energy price, transmission congestion cost, and cost of marginal losses.

On the other hand, PJM also has capacity markets and auxiliary service markets. Capacity price is decided in line with the demand and supply system, and to some extent, it is different from Korea where capacity price is decided according to the government policies. The auxiliary service market consists of frequency adjustment, reserve, black start, and reactive power and is believed to have a similar compensation system to Korea.

Table 4-3 : characteristics of PJM

PJM Electric Exchange Markets	
Energy Market	- Day-ahead Market - Real Time Market - Lost Opportunity
Capacity Market	- RPM Auction Market
Auxiliary Market	- Frequency Regulation - Synchronized Reserve - Day-ahead Scheduling Reserve - Black Start Service, Reactive Service, ETC

However, the fact that PJM compensates the value of reactive power consumed in the electric power grid system is a big difference from the domestic market. In order to supply reactive power to the electric power grid system, the active power output must be reduced, and PJM concedes this value to compensate for the supply of reactive power. Moreover, in PJM, the American Electric Power (AEP) methodology is applied to calculate the annual revenue required to the reactive power supplier in the way of separating the reactive power production from apparent power production. After the authorities' approval, such settlement is carried out through an annual contract between the operators of the electric power grid system and the power plants.

Another difference is the lost opportunity cost (LOC). LOC is the settlement element of the frequency regulations. For the stabilization of the electric power grid system, hydro power plants are generally operated with a low output than the rated output. While LOC is the system that compensates for the loss of power plants' revenue from low output operation, the U.S.' PJM is considered inclusive in terms of stabilizing the electric power grid system by hydro power plants rather than the domestic authorities.

4.2.2. Implications to the domestic electric power market

The value of hydro power under the current compensation system is not properly conceded. However, hydro power can contribute to improve the reliability of the electric power supply since it is faster to start, stop, and adjust power output than other electric power sources. It also responds faster to load fluctuations. Furthermore, it self-starts without external power source and is able to supply-rated power output in a short period of time.

Currently, the settlement amount of the auxiliary service in Korea accounts for only 0.1 % of the total electric power supply settlement. Considering that auxiliary services are an essential element to stabilize the electric power system, sufficient compensation for the value of such services is required through adjusting the unit price.

The U.S. PJM has a more comprehensive and varying compensation system for the electric power supply than Korea's electric power market. The reactive power compensation and lost opportunity cost compensation provided by PJM is not compensated in Korea even though it is not technically difficult, since it is measured and managed by KPX. This has worsened the current revenue of hydro power plants, posing a stumbling block to the development of small and micro hydro power plants. The Korean government has proposed a blueprint to speed up the clean energy development by removing nuclear power plants and old coal-fired power plants, yet the problem remains since the clean energy policy focuses only on the solar and wind power. They are the two most heavily constrained power generation methods because they are very sensitive to the weather. To overcome these weaknesses, the government is spending astronomical budgets to introduce large-scale ESSs. However, the government should first reevaluate its hydro power potential. Hydro power plant is the only resource that can replace nuclear power plant and ESS by utilizing dams and weir, which are semi-permanent structures. In the case of hydro power, if the stored water is abundant, no natural constraints will follow.

According to the K-water's paper on the comparison of hydro electronic power with other power sources in aspect of energy cost (2014), it was found that Koreans are willing to pay additional fees for the use of clean energy in response to global climate change. Therefore, it is encouraged that the government is to promote hydro power for the post-3020 policy.

5. An institutional measures for activating hydro power

5.1. Establishment of institutional direction for activating hydro power

This report proposes two separate systems for vitalizing domestic hydro power generation: the introduction of new settlement elements and the modification of the existing settlement formula. The introduction of the new settlement element will be a way to benchmark the U.S.

PJM market, and this will be applied to the domestic electric power market while the revision of the existing settlement formula should be presented in a way that complements the revision of CP's settlement formula.

5.2. Measures of introducing new settlement elements for activating hydro power

To stabilize the electric power grid system, KPX usually orders the supply of reactive power to each power plant through ‘electric power supply order’. However, due to the characteristics of generators, if reactive power output increases, active power will be reduced to the contrary. To this, the Korean government as stated that it only compensates for active power rather than the production of reactive power.

Despite the government’s stance, reactive power supply to the electric power grid system contributes a lot to the stabilization of the system. Without reactive power, the power grid system collapses. Therefore, this report maintains that the government needs sufficient compensation for the supply of reactive power to the electric power grid system. However, compensation for the reactive power would need a different method than the current SMP system. This is because compensation for the reactive power based on the existing SMP system requires a high cost. The increase in costs in the electric power wholesale market is a burden to the consumers. Therefore, the Korean government should come up with a new compensation system in a way that minimizes the cost increase of consumers.

In addition, the reduction in power output and revenue from the AGC operation should be compensated. Of course, the domestic electric power market compensates the AGC operation, but this is only to the compensation for its contribution to the stabilization of the electric power grid system, complying with the AGC operation. There is no compensation for the output reduction. Therefore, the Korean government should compensate for it.

5.3. Modification of the existing settlement formula for activating hydro power

The most important point of the modification of the settlement formula is that the old CP unit price of the generators, which causes greenhouse gas emissions, should be lowered while the CP unit price should be raised for the newly created low-carbon generators. In other words, the compensation level of CP must be maintained to the usual level. If the total payment of CPs is increased without the consensus of the people, the damage will be greater to customers. In this report, modification of settlement formula is proposed by dividing it into two groups: centralized power generators and non-centralized power generators.

5.3.1. Centralized power generator

The first method is to improve the absurdity of CP derived from the excessive government interference. The Korean government has stopped such interference to RCP, RCF and FSF, and further should try to find out the best unit price by cooperating with the private sector.

The second method is to add a recovery factor to the existing formula of the current CP. The current CP formula is CP = RCP × RCF × TCF × FSF as previously described. The recovery factor (α) is multiplied to this formula, and it is operated between 0.5 and 2 until the fixed cost is recovered. The closer it is to the eco-friendly power plant, the higher the rate. In addition, for generators that have already collected fixed costs, the recovery factor is adjusted between 0 and 1 to reduce abnormal excessive income. This method can be considered as a way to give strong market entry signals to eco-friendly power generators that often face difficulties to recover fixed costs.

Finally, the adjustment of the 'Settlement Adjustment Coefficient' is required. As mentioned earlier, the settlement adjustment coefficient is currently being used without proper standards only to make up the deficit of KEPCO and KPX. However, in determining the settlement adjustment coefficient, it should recognize its rationality by providing specific evidences for calculation rather than the mere notice of the Cost Assessment Committee. This report also suggests to expand the range of 0.0001 to 1.5 instead of the current 0.0001 to 1.0. Under the current system, settlement adjustment coefficient only operates to limit the profits of power plants, but if expanded, it can enhance the equity and rationality by distributing KEPCO's excess profits to power plants. However, it should avoid as much consumers' damage as possible from the adjustment of settlement adjustment coefficient.

5.3.2. Non-centralized power generator

Revenue from non-central power generators is simpler than that of central power generators – SMP and REC sales revenue. However, the concern is that REC also does not guarantee stable profits to power plants. Due to the nature of power generation, most non-central power generators are new-renewable energy, such as solar energy, hydro power, wind power, and tidal power, and stable profit guarantees such eco-friendly energy, making it essential to achieve the post-2030. Certinaly, this is a crucial means for the future of mankind, not only for the post-2030 strategy. It is something that every country in the world should pursue in the future. However, To preserve consumers, excessive profits from renewable energy should naturally be avoided.

To solve this unstable profit of power plants, this report proposes a national purchase of REC. Currently, renewable energy power plants that produce new REC sell REC at contract unit prices through a 1:1 long-term contract with large power plants that are required to purchase REC. However, a profit decrease from renewable energy power plants is inevitable due to the recent fall in the REC unit prices. Therefore, the government should calculate the standard construction and the operating cost for each power plant. It is also required to calculate the price that guarantees the proper profit of the power plant and to purchase REC at a proper price. In addition, large power plants, which have the obligations of supplying REC, should not sign a 1:1 contract with each renewable energy power generator, but purchase REC from the government. In this particular setting, both sellers and buyers can sell/buy REC at reasonable prices.

This national REC management system can manage the problems of over-supply and collusion of purchasing among large power plants. It can also regulate the number of new-renewable energy power plants by appropriately adjusting the REC prices.

Table 5-1 : Measures for activating hydro power plants

<table>
<tr><th>Introducing New Settlement Method</th><th colspan="2">Modifying Existing Settlement Formula</th></tr>
<tr><td rowspan="2">- Compensation for Reactive power
- Compensation for AGC</td><td>Centralized Generator</td><td>- Fixing the problems of CP
- Introducing recovery factor
- Modifying settlement adjustment factor</td></tr>
<tr><td>None Centralized Generator</td><td>- Introducing REC management system by government</td></tr>
</table>

6. Conclusion

Korea's electric power trading market is a limited competitive market, in which only the electric power generation sector has a competitive system. The rest of the system, such as market operation, transmission and distribution of electric power, are exclusively operated by KPX and KEPCO. However, in the competitive electric power generation sector, KEPCO's electric power generation subsidiaries account for most of the Korea’s total electric power generation. In other words, a monopoly. This points out that Korea's electric power market is operated as intended by the Ministry of Trade, Industry and Energy and KEPCO.

In this certain setting, it is almost impossible to revise laws and regulations related to the electric power market in opposition to the will of the Ministry of Trade, Industry and Energy and KEPCO. In the case of KEPCO, there are six subsidiaries that operate nuclear and coal-fired power plants. This serves as the fundamental reason that causes conflicts between the government's strategy to revitalize renewable energy and the actual operation of the electric power market. Therefore, it is necessary to change the position of the Ministry of Trade, Industry and Energy and KEPCO in order to revitalize renewable energy and hydro power development in Korea. Without this premise, it would be impossible to enhance the equity and eco-friendliness of the domestic power market.

Assuming that the preconditions are resolved, the next thing to do is setting the 'electric power market operation rule'. The domestic electric power market is operated under this rule. This includes all criteria for operating and settling the power market, such as SMP determinants and settlement methods.

However, Korea's electric power market rules ignore compensation for several services that hydroelectric power provides to the electric power market. It is necessary to give entry signal of hydro power to the electric power market through the compensation for reactive power and AGC operation which are already applied in PJM.

Among the settlement factors, CP has been the most-used factor by the electric power authorities to control the market price. This is because CP can reflect many different factors. In this context, it is possible to induce the market entry of eco-friendly power plants by adding recovery factors to CPs to give high weight to eco-friendly generators. In addition, the

‘Settlement Adjustment Coefficient’, which was maintained in the name of protecting consumers, must be adjusted to distribute appropriate profits to other various power plants. In addition, it should consider how to simultaneously meet the needs of REC's sellers and buyers by improving the REC system in revitalizing renewable energy and non-central power plants.

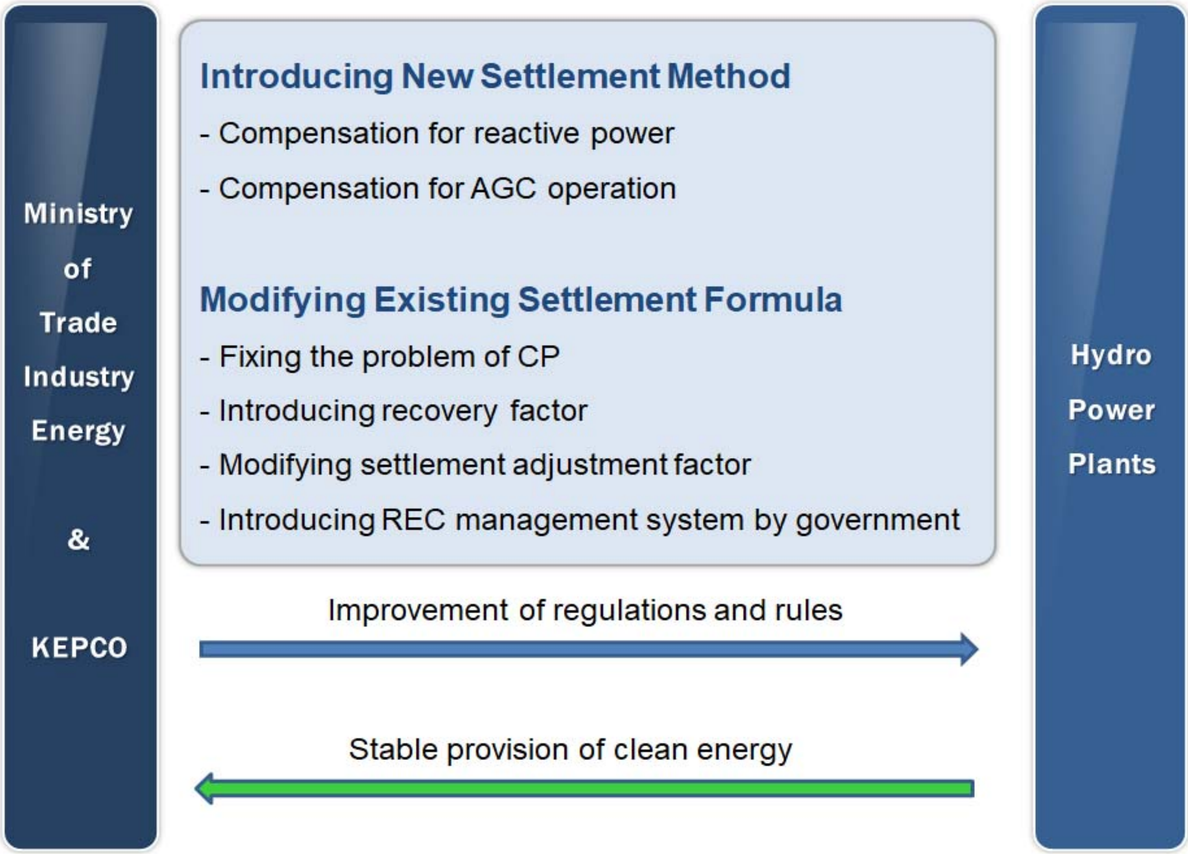

Figure 6-1 : New compensation system to hydro power

There is no system in this world that satisfies everyone. However, a systems must be targeted in a way that it satisfies the society with equity and efficiency. From now on, the Korean government will have to promote eco-friendly energy and create a more reasonable system through the improvement of the electricity trading sector.

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