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Review of Ongoing Debates and Research Associated with Energy Transition Policy in Korea

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Abstract: The transition to cleaner energy usage is accelerating worldwide in an effort to combat the climate crisis. In Korea, there is a social consensus regarding the cause and direction of energy transition represented by an increase in the utilization of renewable energy, improvement in energy efficiency, and decentralization of control. However, no social consensus has been reached for the means and methods of implementing energy transition policies, nor the pace at which they would take effect. In fact, several issues have been subject to heated political debates. In this study, the major issues associated with Korean energy transition policies were examined in terms of the intensity, pace, and cost of energy transition and its impact on the national economy. In particular, the key points of different claims were examined through an in-depth review of the literature on each topic and quantitative data analyses. Based on this study's findings, topics are proposed which can help facilitate furthering debates over Korean energy transition policies.
Key Words: Energy Transition, GHG Emissions, Power Supply Cost, Job Opportunity

I. Introduction

More than 70 countries have participated in the net-zero declaration put forth by the European Union. The President-Elect of the United States also emphasized his pledge to rejoin the Paris Agreement and reduce net greenhouse gas (GHG) emissions to zero by 2050. President Moon Jae-in has also announced that Korea will commit to achieve net-zero by 2050 in October 2020. This announcement is expected to accelerate the energy transition in Korea.

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In Korea, the Moon Jae-in administration has rigorously implemented energy transition policy. In addition to the seriousness of the climate crisis, the Fukushima nuclear accident, the experiences from the dispute over the construction of the Miryang transmission tower, and the fine dust issue have raised awareness of problems of a large-scale centralized energy system focused on nuclear and coal-fired power. Thus, there is a social consensus about the imperativeness and the orientation of energy transition, which is represented by promoting renewable energy, improving energy efficiency, and switching to a decentralized energy system. However, no social consensus has been reached regarding the policy tools and pace to achieve the goal owing to conflicting opinions of stakeholders. This conflict in opinions arises because of concerns about the impact of energy transition on changes in the industrial structure in the energy sector and people's lifestyles. Several issues have been politicized, prompting debate.

The Korean government has introduced misunderstandings and truths about the energy transition policy, and the Korean Energy Information Culture Agency regularly performs fact checks on the energy transition policy. Such involvement of the government shows that debates about the energy transition policy are fierce. The three main issues associated with the debates include the pace of GHG reduction and energy mix change, the increase in power supply cost, and the impact of energy transition policy in the national economy. Closely related with each other, these issues have given rise to a fundamental question on the direction of energy transition policy in Korea. Korea is not the only country with these debates. Germany, a leader in implementing energy transition, has also seen continuous and persistent debates and is trying to reach a social consensus on the issue (Fischer et al., 2016).

In this study, the arguments from different views for the three main issues were investigated through an in-depth review of literature and a quantitative data analysis. We hope that the thorough review of the arguments contributes to overcome the deadlock of the fierce debates. The contents of this paper are as follows. In Section Ⅱ, the energy transition policy in Korea was reviewed, and its achievements were described. In Section Ⅲ, several arguments with the pieces of evidence and the implications of the arguments were investigated for each of the three major issues. In Section Ⅳ, proposals to lead these debates toward a productive direction and their implications for a low-carbon society were presented.

Ⅱ. Outline of Energy Transition Policy in Korea

Energy transition has emerged as a major theme worldwide. The climate crisis, the Fukushima nuclear accident, and technological advances in the field of renewable energy and energy efficiency have jointly made energy transition a global trend (Kuittinen and Velte, 2018). Although the definition of energy transition varies depending on the conditions of each country, the common features of the energy transition worldwide are to increase the proportion of renewable energy, improve energy efficiency, and reduce GHG emissions. Korea also participated in the global trend of energy transition with the inauguration of the 19th government in 2017. In response to public pressure concerning safety issues associated with nuclear power and environmental issues associated with coal-fired power, the 19th government, led by President Moon Jae-in, has sought an energy transition policy with an emphasis on its pledges to phase out nuclear and coal-fired power and increase the proportion of renewable energy.

The background of energy transition in Korea differs from those of other countries primarily in terms of the acceptability of nuclear and coal-fired power. Along with the Fukushima nuclear accident, the conflict over the construction of the Miryang transmission tower has spread skepticism about an energy system that relies on large-scale power generation capacity. As the fine dust problem in Northeast Asia became more serious, the opinion that coal-fired power, which is one of the major sources of fine dust, should be reduced has gained strength. Under this unique background, the direction of energy transition policy in Korea is to simultaneously phase out nuclear and coal-fired power and to increase the proportion of renewable energy instead (Han, 2020).

The initiation of the energy transition policy in Korea is the public deliberation on continuing the construction of Shin-Gori nuclear reactors 5&6 for the duration of July-October, 2017. The recommendation of the Public Deliberation Committee for Shin-Gori Nuclear Reactors No 5&6 (PDCS, 2017) was that the construction of the nuclear reactors should be resumed, but that no more nuclear power plants should be built. The government announced the “Energy Transition Roadmap” (MOTIE, 2017. 10.24.) in October 2017 by reflecting these public deliberation results. The core contents of the roadmap include increasing the proportion of renewable power generation and gradually decreasing the nation’s dependency on nuclear power plants. This roadmap presented a target to reduce the number of nuclear power plants from 24 to 14 by 2038 and declared that the new construction of nuclear power plants and the lifetime extension of the existing nuclear power plants will not be allowed. This roadmap also presented a target to increase the proportion of renewable power generation from 7% to 20% by 2030. The policy direction of the Energy Transition Roadmap was specified through the "Renewable Energy 3020 Plan" (MOTIE, 2017a) and the "8th Basic Plan for Long-Term Electricity Supply and Demand (BPLE)," which was announced later (MOTIE, 2017b).

Along with the promotion of the energy transition policy, the GHG emission reduction target was also reinforced. In July 2018, the government announced the "Amendment to 2030 Greenhouse Gas Roadmap" (Office for Government Policy Coordination, 2018). The roadmap increased the share of domestic reductions from 27.5% to 32.5%, to be achieved by 2030, in the GHG emission reduction target. As a result, the GHG emission target by 2030 for the power generation sector was revised from 223.1 $MtCO_2eq$ to 192.7 $MtCO_2eq$, while the revised pathway has not yet been identified.

In June 2019, the "3rd Energy Master Plan" (MOTIE, 2019a) was announced. The plan extended discussions on transition focused on the energy mix of the power generation sector to the structure of energy supply and demand and institutions. On the demand side, it sets a goal to reduce final energy consumption by 18.6% below the BAU (business-as-usual) level by 2040 by innovating the energy consumption structure. On the supply side, it proposes to increase the share of renewable power generation to 30-35% by 2040. The plan emphasizes the importance of decentralized energy system and promotion of future energy industries from an industrial perspective. It also proposes policy directions to reform energy market systems by emphasizing the need to introduce a real-time market and a supplementary service operation system in the power sector.

In July 2020, the government announced the "Korean Green New Deal Plan" (Office for Governmental Policy Coordination, 2020a). This plan is a fiscal stimulus package to invest USD 61.8 billion by 2025 in green transition for moving toward a net-zero society. Naturally, it is expected to contribute to accelerating energy transition. In October 2020, President Moon Jae-in announced a commitment to net-zero emissions by 2050 in his speech at the National Assembly. In December 2020, the government announced the "2050 Net-zero Emissions Strategy" (Office for Governmental Policy Coordination, 2020b) to realize the presidential commitment.

According to the assessment of KEEI (2020a), the energy transition policy in Korea achieved the expected outcomes. Both the proportion of renewable power generation and the amount of renewable power-generation capacity exceeded the target path presented in the "Renewable Energy 3020 Plan". A series of policies to reduce coal-fired power generation have successfully decreased PM (particle matter) 2.5 emissions by more than 45% over the last three years (MOTIE, 2020.3.16.). The government has also gradually modified an institutional base for energy transition. It installed a small-scale power exchange market in January 2019, to increase the supply and utilization of distributed resources, such as small-scale PVs and ESS. In April 2019, the tax rates imposed to fuel for power generation were revised by reflecting environmental costs. In December 2019, the government amended the Enforcement Decree on the Framework Act on Low Carbon, Green Growth to change the BAU-based 2030 GHG reduction target to an absolute quantity-based target. Boosted by these efforts, the energy supply and demand structure was also improved in terms of decarbonization (KEEI, 2020a). The proportion of nuclear power and coal in total primary energy supply decreased from 41.9% in 2015 to 37.3% in 2019. The proportion of fossil fuels in total final energy consumption decreased from 76.2% in 2015 to 75.5% in 2019.

Despite these achievements, debates over the energy transition policy have persisted. The government has performed a U-turn on the nuclear power policy, and this U-turn provoked such debates. The "2nd Energy Master Plan" (MOTIE, 2014) suggested that a sharp reduction in nuclear power is not desirable and that the requirement of nuclear power capacity would be 43GW by 2035. Conversely, the "Energy Transition Roadmap" (MOTIE, 2017.10.24.) announced that nuclear power capacity will be reduced to 20.4GW by 2031. In addition, the government announced that the phase-out of coal-fired power will be accelerated to resolve the fine dust problem (MOTIE, 2017b). The direction of the energy transition policy to simultaneously phase out nuclear and coal-fired power and to increase the proportion of renewable energy has caused various debates. Such debates can be summarized as focusing on the following topics: the intensity and pace of the energy transition, the cost of the energy transition, and economic impact of the energy transition. These are discussed in detail in the next Section 3.

Ⅲ. Debates on Energy Transition Policy in Korea

1. Intensity and Pace of Energy Transition

The debates on the intensity and pace of energy transition refer to questions about the proper level of GHG reduction target and the appropriate pace of GHG reduction efforts.

First, debates on the appropriate level of GHG reduction target, which determines the intensity of energy transition, were examined. The Korean government submitted a Nationally Determined Contribution (NDC) that proposed an economy-wide target to reduce GHG emissions by 37% below

BAU by 2030. According to the NDC, the GHG emission target of Korea by 2030 is 536 $MtCO_2eq$. This target was evaluated as “very aggressive” by some (Lee, 2015; BNEF, 2015) but “highly insufficient” (CAT, 2020) by others. What is a reason for the conflicting evaluations over a single target?

The 2030 GHG reduction target was considered “aggressive” in the case of considering an industrial structure that highly relies on energy-intensive industries and a historical GHG emissions path. The Korean economy has been highly dependent on manufacturing, especially energy-intensive industries. For example, Korea ranked second for the proportion of the manufacturing industry and the first for the proportion of energy-intensive industries in terms of value-added among high-income OECD countries in 2018 (〈Table 1〉). Considering this industrial structure, a sudden reduction in GHG emissions may incur high costs and weaken industrial competitiveness (Lee, 2015). During the period between 1990 and 2019, GHG emissions in Korea increased by 3.1% on average per year. To achieve the 2030 GHG reduction target, GHG emissions must be reduced by 2.4% per year from now on. Hence, this target is considered “very aggressive” owing to how challenging it will be to achieve.

〈Table 1〉 Proportion of value added in manufacturing and energy-intensive industries among high-income OECD countries

Country	Value added in manufacturing		Value added in energy-intensive industries	
	2000	2016	2000	2016
Australia	10.2%	6.2%	6.5%	3.8%
Canada	-	10.3%	-	3.7%
France	12.3%	11.4%	3.7%	3.4%
Germany	21.5%	23.1%	6.9%	6.4%
Italy	17.6%	16.3%	5.6%	4.9%
Japan	18.7%	20.4%	3.3%	3.4%
Korea	29.3%	28.8%	8.3%	8.1%
Netherlands	12.6%	12.0%	3.8%	4.0%
Norway	30.2%	33.6%	1.9%	1.5%
Poland	12.1%	20.0%	14.2%	7.7%
Spain	16.5%	12.4%	5.7%	4.1%
Sweden	18.3%	15.3%	4.2%	3.4%
Switzerland	18.2%	20.1%	3.7%	2.4%
UK	14.2%	10.2%	4.0%	2.6%
US	13.0%	11.9%	5.3%	4.2%

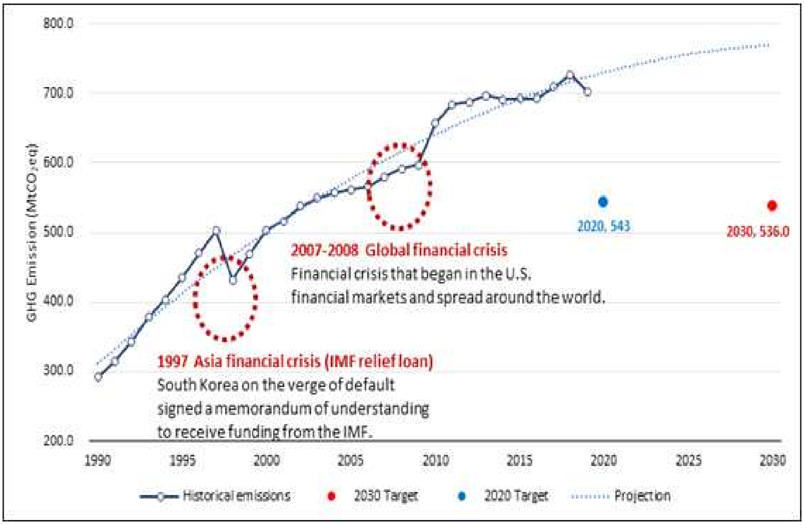
Note: 1) OECD National Accounts data (Dataset: 6A. Value added and its components by activity, ISIC rev4, https://stats.oecd.org/) were used for calculating the proportion of value added in manufacturing and energy-intensive industries for OECD countries except Korea; 2) The National Account data from the economic statistics system of the Bank of Korea (http://ecos.bok.or.kr/) were used for calculating he proportion of value added in manufacturing and energy-intensive industries for Korea; 3) for OECD countries except Korea, energy-intensive industries are defined as the sum of the manufacture of coke and refined petroleum products (V19), manufacture of chemicals and chemical products (V20), manufacture of rubber, plastics and other non-metallic mineral products (V22_23), and manufacture of basic metals and fabricated metal products except machinery & equipment (V24_25); 4) and for Korea, energy-intensive industries are defined as the sum of the manufacture of coke and refined petroleum products, manufacture of chemicals and chemical products, manufacture of non-metallic mineral products, and manufacture of basic metals

The evaluation that the 2030 GHG reduction target of Korea is “insufficient” is due to the prediction that it would be difficult to achieve the target of 2℃ or less, as required in the Paris Agreement, with the current level of reduction efforts. According to the Carbon Action Tracker

(CAT), the 2030 GHG reduction target of Korea is "highly insufficient" because it is not consistent with keeping global warming to below 2℃ increase and is instead consistent with keeping global warming between 3℃ or 4℃ increase. Climate Analytics (2020) insists that a target of Korea to keeping global warming to 1.5 ℃ increase ranges from 291 to 401 $MtCO_2eq$ by 2030 and that it should be reinforced by 42–217 $MtCO_2eq$ considering the fair share.

The opinion that the 2030 GHG reduction target of Korea is "aggressive" is meaningful because it addresses the practicality of the target when taking the Korean economic conditions into account. However, it limits progressive discussions to actively overcome the path dependency problem. As illustrated in Figure 1, it is almost impossible to achieve the GHG emission target of Korea by 2020 (543 $MtCO_2eq$), which was presented at the UN Climate Change Conference in Copenhagen, Denmark in 2009. The biggest challenge to meeting the 2020 target is that the energy consumption of energy-intensive industries increased in the process of overcoming the global financial crisis in 2008 (MOTIE, 2014). It implies that industrial restructuring did not move toward a low-carbon economy in Korea (Jeong and Kim, 2013).

〈Figure 1〉 Historical emissions, projection and key targets in Korea



In contrast, the opinion that the 2030 GHG reduction target of Korea is "highly insufficient" emphasizes that the inertia in the economic system that depends on energy-intensive industries should be overcome and that when considering the responsibility to the international community, stronger GHG reduction efforts are required. However, it is difficult to define the equity or fair share of GHG emissions because there are various measures to define that share (BNEF, 2015; Pan et al., 2017). In this respect, the argument that the Korean government should set a stronger target has been criticized for lack of feasibility.

Most academics agree that GHG reduction target level can be evaluated considering various criteria. BNEF (2015) assessed that the 2030 GHG reduction target of Korea is highly ambitious in terms of the change in emission intensity relative to 2010 and in terms of abatement required to achieve national INDC targets as a proportion of estimated emissions over 2012-2030. Lee and Park (2017) reported that the target is strong among OECD countries in terms of the absolute amount of reduction but is weak in terms of relative indicators, i.e., GHG emissions per capita and GHG intensity. Oh (2016) evaluated that the target is aggressive in terms of proportion indicators, i.e., proportions of cumulative emissions, GDP, and CO_2 emissions of a certain country, but is insufficient in terms of relative indicators, i.e., relative indicators for emissions per capita, income per capita, and emission units.

Next, debates on the implementation pace of GHG reduction efforts. The pace is identical to that of energy transition in effect. A social consensus has been generally reached on the direction of a future energy system with an increase in the proportion of renewable energy and a decrease in the proportion of nuclear and fossil fuels (Yun, 2018). However, debates on the timing of phasing out nuclear and coal-fired power and the rate of renewable energy dissemination are ongoing.

President Moon Jae-in pledged to cancel the new construction of nuclear power plants, prohibit the extension of the lifetime of old nuclear power plants, and close Wolseong Nuclear Reactor 1. After the inauguration, he stopped the construction of Shin-Gori Nuclear Reactors 5&6 in which a sunk cost of KRW 1.6 trillion had already been invested. This decision brought about fierce conflict between the pro- and anti-nuclear groups. As such, the government implemented public deliberation on this issue, and the results were as follows (PDCS, 2017). First, 59.5% of the respondents supported the resumption of construction of Shin-Gori Nuclear Reactors No. 5&6. Second, 53.2% of the respondents favored reducing the use of nuclear power. The government resumed construction of the Shin-Gori nuclear reactors 5&6 by reflecting the results of the public deliberation but canceled the construction of the other nuclear power plants. Its philosophy is reflected in the "Energy Transition Roadmap" (MOTIE, 2017.10.24.).

The public deliberation resolved the exhausting social debate over the construction of Shin-Gori Nuclear Reactors 5&6 (Yun, 2018; Chung, 2020), but no consensus has been reached regarding the speed of nuclear phase-out. Some insisted that nuclear power should serve as an alternative to fossil fuels and a stable energy supply source until technologies and economic feasibility of renewable energy become sufficiently mature (Park, 2017; Nguyen, 2019). In particular, this argument is supported by the opinion that a careful approach is required considering international competitiveness and job opportunities of the Korean nuclear industry. Others have insisted that nuclear power should be rapidly phased out for reducing the risks of accidents, decommissioning issues, and social conflicts surrounding site selection and radioactive waste management (Yun, 2003; Yang, 2020.7.21.).

There is also an ongoing debate about the rate of renewable energy dissemination. The Korean government set a goal to increase the share of renewable energy in gross power generation to 20% by 2030 and to 30–35% by 2040 (MOTIE, 2017a, 2019a). The opinions perceiving this goal as being insufficient compared to other advanced countries (Lee, 2017) and those concerning about the impact of rapid dissemination of intermittent renewable energy on the stability and reliability of energy system (Min et al., 2018, 2020; Lee, 2020) are mixed. This debate became clear in the process of setting a goal for the share of renewable energy by 2040 during the establishment of the 3rd Energy Master Plan. The working group of the plan proposed 25–40% as the target share of renewable energy by 2040 (Working Group for the 3rd Energy Master Plan, 2018). When this proposal was investigated by experts, it was found that the cost from intermittency of renewable energy would sharply increase if the share exceeds 35% (MOTIE, 2019a).

For a reduction in coal-fired power, there are relatively fewer conflicting opinions compared to those on nuclear power or renewable energy. This is because coal-fired power is recognized as the main source of GHG emissions and PM pollution (BNEF, 2015; Lee and Kim, 2019). There is, however, a conflict between the opinion that the planned schedule of phase out should be advanced (Lee and Kim, 2019; Climate Analytics, 2020) and the opinion that it should be complied with (Bae, 2019). The former puts an emphasis on the severity of climate crisis and PM pollution. The latter is concerned about an increase in power generation cost caused by a reduction in coal-fired power generation and the negative impact on the local communities with coal-fired power plants.

2. Cost of Energy Transition

Debates have continued regarding whether the energy transition policy would increase power supply cost, which would result in increases in electric charges. On one side, it is insisted that an increase in power supply cost would cause an increase in electricity charges if inexpensive coal-fired and nuclear power generation is reduced and relatively expensive renewable power generation is expanded. The government, however, has presented an opposing argument. For example, there was a debate on whether the energy transition would increase the electric charges at a confirmation hearing for a ministerial candidate of the Ministry of Trade, Industry and Energy (MOTIE), which was held in the National Assembly in July 2017. The candidate answered that there will be no increase in electric charges caused by energy transition because the cost of nuclear power generation will increase and that of renewable power generation will decrease over the long term.

This event posed the following question: will there be no cost change caused by energy transition indeed? Works of literature have commonly pointed out that it is likely to increase power supply costs to simultaneously phase out coal-fired and nuclear power. According to the KEEI (2017.6.20.), the simultaneous phasing out of coal-fired and nuclear power will increase power generation costs by 21% in 2029 compared to the cost in 2016. Jang (2018) reported that the power generation cost in 2022 will increase by 4.7% compared to the cost in 2017 to cover the environmental costs of power generation using fossil fuels and achieve the GHG reduction target by 2030 based on the 8th BPLE. Kim et al. (2019) compared the social costs when the capacity and utilization rate of nuclear power were changed to the levels specified in the 7th and 8th BPLE under the assumption that the target path of "Renewable Energy 3020 Plan" was maintained. They estimated that the social cost of the 8th BPLE will increase by up to 22% by 2030 compared to the cost of the 7th BPLE. Cho et al. (2019) found that the energy transition policy will increase direct power generation cost by 18.9% as of 2029, but it will contribute to reducing air pollutant emissions. Choi et al. (2020) analyzed the direct generation cost and the multi-criteria decision making (MCDM) score, which reflects technical, economic, environmental, and social aspects of generation technologies. Their results showed both the direct cost and MCDM score were lower for the 8th BPLE compared to those for the 7th BPLE.

The central basis of the arguments in the literature is that although the cost of renewable energy is rapidly declining, it is still considerably higher than the costs of nuclear and coal-fired power (Hong and Brook, 2018). Table 2 demonstrates the LCOE (Levelized Cost of Energy) estimates of nuclear power, coal-fired power, LNG CCGT, and PV in the literature on the Korean case. Although the LCOE estimates are slightly different from literature to literature, the LCOE estimates of PV are consistently the most expensive and those of nuclear power are the cheapest as of 2017. It is expected that the energy transition policy of Korea will increase social costs as well as the direct cost incurred in the power generation sector in the short term. In 2030, however, the ranking of LCOE estimates of the power sources will be reversed. According to the analysis of KEPCO (2018) and KEEI (2018), the PV is likely to be superior to nuclear and fossil-fuel power generation in terms of social cost by 2030.

Table 2 implies that the energy transition policy will contribute to decreasing the social cost of power generation in the long run if technological development successfully drives down the LCOEs of renewable power generation (Hwang et al., 2019). Considering the criticism that the external cost of nuclear power presented in Table 2 is underestimated (Cho et al., 2018; Lee, 2018), PV technology is the most competitive in terms of social cost in the long term. Furthermore, the possibility of premature deaths and productivity degradation caused by air pollution supports that the energy transition policy will eventually reduce the social cost of power generation in the long run. The social costs of renewable energy, however, are also likely to increase compared to the LCOE estimates presented in Table 2 when taking the additional cost required to improve grid reliability against intermittent renewable energy into account (MOTIE, 2019a).

〈Table 2〉 LCOE estimates by power sources in literature

Unit: KRW/kWh		Nuclear power	Coal-fired power	LNG CCGT	PV
KEPCO (2018)	Total cost (in 2017)	73.63-83.84	83.4-100.29	88.09-89.89	129.54-151.42
	- Private cost	47.96	57.92	79.57	-
	- Indirect cost	25.97-35.88	25.48-42.37	8.52-10.32	-
	- (External cost)	23.68-33.39	22.25-39.14	7.88-9.62	-
	Total cost (in 2030)	75.26-84.97	92.75-109.64	92.92-94.72	83.54-98.42
	- Private cost	49.59	57.92	79.57	-
	- Indirect cost	25.67-35.38	34.83-51.72	13.35-15.15	-
	- (External cost)	23.17-32.82	33.65-50.54	12.71-14.51	-
KEEI (2018)	Total cost (in 2017)	61.17-69.58	81.22	92.00	118.65-147.6
	- Private cost	49.5-55.33	55.71	81.40	118.65-132.97
	- Indirect cost	11.67-14.25	25.52		0-14.63
	- (External cost)	8.46-10.87	24.34	9.97	-
	Total cost (in 2030)	68.84-78.27	100.06	98.71	66.03-94.88
	- Private cost	57.17-64.02	60.52	82.15	66.03-80.25
	- Indirect cost	11.67-14.25	39.54	16.56	0-14.63
	- (External cost)	8.46-10.87	38.36	15.92	-
Cho et al. (2018)	Total cost (in 2017)	59.67-66.06	96.06-113.04	116.44-119.89	-
	- Private cost	51.72	58.25-67.05	93.79-108.76	-
	- Indirect cost	7.95-14.34	29.01-54.79	11.13-22.65	-
	- (External cost)	5.62-12.01	28.29-54.07	10.75-22.27	-

Note 1) LNG CCGT stands for a combined cycle gas turbine using liquified natural gas; 2) the private cost of coal-fired power and LNG CCGT includes construction, operation, fuel, and transmission costs; 3) the private cost of nuclear power additionally include radioactive waste disposal and decommissioning costs; 4) the indirect cost of nuclear power, coal-fired power and LNG CCGT includes policy and external costs, which consists of accident risk response, carbon emission, and air pollution costs; 5) the private cost of PV includes module, BOS (balance of system), operation and maintenance, and abolition costs; 6) the indirect cost of PV includes land, licensing/design supervision, and other incidental costs; 7) and the fuel taxes and Grid reinforcement cost are excluded from the indirect cost.

Similar to Germany and Japan, where electric charges increased during the energy transition process (Fischer et al., 2016; Kim et al., 2018), the energy transition policy of Korea is also expected to eventually increase electric charges to recover increases in the direct cost of power supply over the short term. The thing is, in Korea, electric charges have long been subject to direct government regulation. In recent years, the electric tariffs have been suppressed to below the power generation cost due to the price stabilization of consumer goods and services (Kim and Shin, 2016; Jung et al., 2019). Then, if electric charges properly cover the cost of energy transition and externalities from the generation base and traditional power sources, they are likely to be increased from the current level.

This elucidates another question, that is, whether Korean people are ready to accept increases in electric charges caused by the energy transition policy. Table 3 summarizes the results of previous studies on the willingness to pay (WTP) of Korean people for energy transition in terms of monthly electricity bills (Lee et al., 2017; Jang, 2017; GESI, 2018; Kim et al., 2020; KEEI, 2020b). The results show that Korean people are willing to additionally pay KRW 3,109 to 13,680 in terms of monthly electricity bills for energy transition. The WTP estimates commonly indicate that Korean people are willing to submit increases in electric charges for energy transition, even though they significantly varied depending on the literature. Among the respondents, however, the proportion of protest bidders ranged from 20% to 56%, indicating that many people do not agree with the increase in electric charges for energy transition and the process of persuading people will be a must in the future.

〈Table 3〉 WTP estimates for energy transition in literature

Literature	Survey period	Sample size	Hypothetical scenario	Payment vehicle	Mean WTP (KRW/month)	Protest bid-ders
Lee et al. (2017)	Oct. 2014	1,000	Substitution of traditional energies with renewable energy	Monthly electricity bill	3,402 (substitution of nuclear power) 3,109 (substitution of coal)	28.1% (substitution of nuclear power) 31.2% (substitution of coal)
Jang (2017)	Oct. 2017	1,048	Energy transition that reduce the share of nuclear and coal and increase the share of LNG and renewables in an energy mix	Monthly electricity bill	13,680	No in-formation
GESI (2018)	Jan. 2018 – Feb. 2018	1,225	Transition toward a safe and eco-friendly energy system	Monthly electricity bill	No information	20%
Kim et al. (2020)	Jan. 2018	1,000	Implementation of Renewable 3020 Plan	Monthly electricity bill	3,535	49%
KEEI (2020b)	Not reported	1,000	Increase the share of renewable electricity generation	Monthly electricity bill	6,615	56.76%

3. Impact of Energy Transition on National Economy

The impact of the energy transition policy on the national economy can be categorized into microscopic and macroscopic impacts. The microscopic impact refers to the resource allocation in energy industries caused by the change in the power generation mix. The macroscopic impact refers to the influence of the energy cost increase or GHG reduction policy caused by energy transition on the overall economy. The core of the debate is whether the direction of energy transition policy that simultaneously phases out nuclear and coal-fired power and increases the proportion of renewable energy brings about a decrease in job opportunities in the energy industry sector.

The debate started in earnest from the release of the Deloitte report (2018). Deloitte (2018) estimated the manpower demand of the domestic nuclear power industry by 2030 under four scenarios depending on the number of orders for overseas nuclear power plants on the premise of the Korean energy transition policy that early closes nuclear power plants and cancels new construction of power plants. According to Deloitte (2018), under the most pessimistic scenario without nuclear power plant export, the manpower demand will decrease by up to 10,000 people by 2030 compared to the manpower demand in 2018. The results made headlines and then, brought about concerns that the energy transition policy would depress the nuclear power industry. MOTIE (2018.9.1.) clarified that the analysis of Deloitte (2018) did not reflect the government steps forward supplementation of the nuclear power industry. MOTIE (2018.9.1.) explained that such negative impacts will be minimized through government support for expanding the export of nuclear power plants and for maintaining the industrial ecosystem.

Despite the government's clarification, however, the concern that the power mix transition will have a negative impact on job opportunities in energy industries was not lessened. NEA·IAEA (2018) estimated that the total lifetime employment of site preparation, construction, and operation and maintenance of a single 1,000 MWe-scale nuclear power plant is about 200,000 labor- years. Because their estimation was based on the analysis of the U.S. case, and it is difficult to apply to the Korean case in the same manner. However, the Korean media criticized that up to one million jobs will be lost due to the phase-out of nuclear power by citing their estimation.

A decline in job opportunities due to the phase-out of coal-fired power has also been embroiled in controversy. In November 2019, the government decided to close six old coal-fired power plants by early 2021 to reduce PM emissions. The media estimated that approximately 1,000 jobs will be lost owing to the closure of the corresponding power plants and emphasized a need to respond to this issue. Lee and Kwon (2019) emphasized that measures to minimize the negative impacts - including job losses - of the early closure of coal-fired power plants on the local economics and communities should be placed. They pointed out that the phase-out of coal-fired power may create tension between environmental and labor movements and insisted that all stakeholders, including the government, workers, and local communities, should work for a fair transition.

There have been claims that the energy transition policy will have a positive impact on the Korean energy industries in compliance with the rapid growth of renewable energy dissemination worldwide. ILO (2018) predicted that if efforts to meet the Paris Agreement of restraining global temperature rise to 2 ˚C continue, 18 million new jobs would be created worldwide. IRENA (2020) reported that jobs in the global renewable energy sector increased from 7.28 million in 2012 to 11.46 million in 2019. In particular, job increases in the PV and wind power sectors are remarkable. In these sectors, 3.75 million jobs (1.36 million in 2012) and 3.58 million jobs (2.40 million in 2012) were created, respectively. However, there are concerns that the indicators of domestic renewable energy industries do not reach global growth trends due to the fierce competition in the global market and falling prices for renewable energy generation. As shown in Table 4, in Korea, the number of workers in renewable manufacturing decreased by 3.9% compared to the number of workers in the previous year. In particular, as Chinese companies rapidly increase their market share in the global PV market based on the economy of scale, there are concerns that Korean companies don't benefit from the energy transition policy in Korea. The government announced the "Competitive Programs for Renewable Energy Industry" (MOTIE, 2019b) to leap forward to a leading country of renewable technologies and to bring positive effects on the national economy.

〈Table 4〉 Sales and employments of renewable energy sector

Category	2017		2018 (provisional)			
	Sales [100 million KRW]	Number of workers [persons]	Sales [100 million KRW]	Number of workers [persons]	Increase/decrease from last year [%]	
					Sales	Number of workers
Renewable manufacturing (Official statistics)	41,745	14,452	46,392	13,885	11.1	△3.9
Renewable service industries (provisional)	32,780	20,129	43,940	21,330	34.0	6.0
Construction/Installation	29,210	15,292	39,940	16,413	36.7	7.3
• PV	15,260	5,721	20,210	6,076	32.4	6.2
• Wind power	7,670	5,951	11,620	6,637	51.5	11.5
• Fuel cell	90	257	120	407	33.3	58.4
• Geothermal/hydrothermal	3,710	1,816	4,840	1,741	30.5	△4.1
• Hydropower/ocean	1,440	861	2,080	818	44.4	△5.0
• Bio	270	429	140	408	△48.1	△4.9
• Waste	770	257	930	326	20.8	26.8
Other related service industries	3,570	4,837	4,000	4,917	12.0	1.7
Total renewable industries (provisional)	74,525	34,581	90,332	35,215	21.2	1.8

Note: 1) The data were gathered from the 「Renewable energy industry statistics in 2018」 (KEA, 2019a) and the 「Survey results on the renewable energy service industries during the period from 2017 to 2018」 (KEA, 2019b); 2) there are sample errors because the values were estimated using sample survey data; 3) the 2018 values are provisional; 4) the solar thermal sector in construction/installation was not included due to the limited number of samples; and 5) other related service industries: Education, consulting, operation/maintenance, etc.

Hong et al. (2019) and Kim and Jeon (2020) quantitatively analyzed the impact of energy transition on the national economy. Hong et al. (2019) estimated the total number of jobs created in the power sector up to 2050 for four scenarios using the Long-range energy alternatives planning (LEAP) system model. Their results indicated that an increase in the proportion of renewable energy and a decrease in energy demand leads to more jobs in the power sector. Hong et al. (2019), however, applied the employment multipliers presented by Wei et al. (2010) rather than those derived based on the Korean data. Wei et al. (2010) calculated the employment multipliers of ten energy technologies by examining the U.S. cases. In the study of Wei et al. (2010), Solar PVs exhibited the highest employment multipliers (0.87 job·years/GWh), followed by energy efficiency (0.38 jobs·years/GWh). Coal and nuclear power showed the lowest multipliers (0.11 and 0.14 job·years/GWh, respectively). Therefore, it is unlikely that Hong et al. (2019) properly reflect the structure of the Korean energy industry.

Kim and Jeon (2020) estimated the economic effects of the power mix transition using the 2014 input–output table of South Korea. They found that the negative effects of the phase-out of nuclear power will be largely offset by the positive effects of the growth of the renewable energy industry. In specific, they predict that the total induced output of the nuclear power sector will decrease from USD 14.3 billion by 2025 to USD 8.1 billion by 2050 due to the value-added will also decrease from USD 5.8 billion by 2025 to USD 3.3 billion by 2050. The total induced output of the renewable energy sector was expected to increase from USD 16.0 million by 2025 to USD 37.0 million by 2050, thereby offsetting the negative effects of the phase-out of nuclear power. The results, however, require a careful interpretation because the authors assumed that the input–output structure in 2014 will be maintained until 2050.

There is a growing body of literature on analyzing induced effects by the power source. Choi and Jo (2019) analyzed that nuclear power has the highest value-added inducement effect (0.237), followed by thermal power (0.110) and renewable energy (0.034) based on the 2020-2014 input-output table. Kang et al. (2019) reported that the value-added inducement effect of renewable energy (0.7204) is higher than that of thermal power generation (0.5039) and that the employment inducement effect of renewable energy (7.7478 persons/billion KRW) is higher than that of thermal power generation (2.6234 persons/billion KRW) based on the 2014 input-output table. Based on the 2015 input-output table, Kim and Seo (2019) reported that PVs exhibited the highest value-added inducement coefficient (1.23754), followed by wind power (1.25048), other renewable energy (1.21360), and conventional power generation (0.82925). They also found that other renewable energy showed the highest employment inducement coefficient (5.99735 persons/billion KRW), followed by conventional power generation (5.64464 persons/billion KRW), wind power (4.10527 persons/billion KRW), and PV (4.03405 persons/billion KRW). The literature introduced earlier used the input-output tables based on similar periods, but they exhibited different results. The reason for their differences appears to be the process of dividing the power sector into nuclear power, thermal power, and renewable power.

Therefore, there are still significant uncertainties in the direction and scale of the impact of the energy transition policy on the national economy. Because the works of literature are based on numerous assumptions, it is risky to draw a conclusion based on specific research results. From the academic perspective, it is necessary to improve methodologies for elaborating the impact of the Korean energy transition policy on the national economy. From the policy perspective, it is important for the stakeholders of energy transition to continue discussions in a fair and objective manner. The thing is not the expected impact of energy transition itself, but the way to minimize negative effects and to amplify positive effects.

Ⅳ. Discussions and Conclusions

Energy transition drives a paradigm shift in the objectives of energy policy worldwide - towards decarbonization and decentralization, and digitalization. In this context, debates over the Korean energy transition policy can be interpreted as a contention between justification and practical benefits. It is necessary to responsibly participate in keeping global warming below the 2 ℃ (or 1.5 ℃) for adapting to the climate crisis as an OECD member country. Such responsibility will eventually require the achievement of 2030 GHG reduction and 2050 net-zero emission goals. In terms of justification, we need to positively assess the Korean government's strong expression of commitment to GHG reduction in compliance with the realization of trade barriers to GHG emission, including the carbon border adjustment mechanism as a part of the European Green Deal. In terms of practical benefits, the rapid GHG reduction may weaken the backbone of Korean economy, which has depended heavily upon energy-industries and exports. It may also cause several side-effects, i.e. a sharp rise in power supply cost, falling off the local economy based on fossil fuels, and job instability. Is there any change to have our cake and eat it? By reviewing a large body of literature, we found that the keys are the rebirth of manufacturing based on technological advances. and the full-scale reform of the energy system.

To achieve the 2030 GHG reduction goal and the 2050 net-zero emission goal, it is necessary to take a different approach for each goal. For the target by 2030, which is the near future, it would be desirable to harmoniously apply policy measures and technological options, which are currently conceivable. When it comes to making a strategy to meet the 2030 goal, it, thus, is reasonable to put importance on the social cost and the impacts on the national economy. However, we need to take a different approach for the target by 2050, which is a relatively distant future. Only an ambitious vision of net-zero emissions has been just set. To make a strategy for the 2050 target, it is important to reach a national consensus which secures procedural justification. Conflicts among different opinions are expected during this process. More studies and discussions are required to address these problems, but some implications can be found based on the existing literature.

First, it is required to continue discussions based on transparency and information disclosure. Once a national consensus (i.e., value congruence) securing procedural justification is derived, it should be followed by legislation. The legislation will help to secure policy consistency and lower uncertainties impeding private investment and participation. Second, it is necessary to innovate outdated energy systems and institutions by normalizing electric charges, restructuring the power industry, and adjusting the role of public enterprises in the energy sector. Strategies should be prepared for the risk of stranded assets, regional recession, and job losses. Finally, it is necessary to overcome energy island isolation. It is hard to expect that energy cooperation in Northeast Asia will be achieved in the near future because of the UN sanctions on North Korea and Russia.

It is unlikely, however, that this situation will continue by 2050. In preparation for the distant future, it is desirable to establish a plan to construct a 'Northeast Asia Super Grid' that can actively utilize the renewable energy potential of Northeast Asia. The plan should include strategies to preemptively find opportunities to produce green hydrogen using renewable energy potential in the Northeast Asia region.

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