Asia International Grid Connection Study Group Third Report

July 2019

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Introduction

Over the three years since its establishment in July 2016, the Asia International Grid Connection Study Group (the "Study Group") has discussed the possibility of international grid connections between Japan and other Northeast Asian countries.

In the first term, the Study Group clarified the background to the expansion through interconnectors of the electric power trade in Europe in recent years and the basic approaches utilized, and also studied the contrasting situation of Northeast Asia. International grid connections spur the formation of cross-border markets and the resulting competition serves to raise economic efficiency; they help to stabilize the power supply because reserve capacity is shared; and, as the ultimate form of cross-regional transmission operations, they offer a solution to renewable energy output fluctuations. These specificities, which equally apply to Northeast Asia, were laid out in the Study Group's Interim Report released in April 2017.

In the second term, multiple specific routes for interconnectors between Japan and South Korea and Russia were outlined, the construction costs estimated, and a business model considered for recovering the costs based in part on field surveys of international grid connections in North America. Assuming an interconnector between Japan and Russia from 161 kilometers to 1,255 kilometers in length, construction costs were calculated from 110.0 billion JPY to 430.5 billion JPY. For an interconnector between Japan and South Korea from 226 kilometers to 627 kilometers, construction costs were calculated from 129.0 billion JPY to 246.5 billion JPY. The Study Group showed that these investments would be fully recoverable even when accounting for enhancement made to the domestic grid, and these findings were compiled in its Second Report, which was released in June 2018.

Subsequently, in fall 2018, the Study Group conducted field surveys in the United Kingdom (UK) and Spain, areas with less favorable conditions for international grid connections, and in the third term, analyzed in detail the benefits of such connections and studied the various energy security-related issues involved in international grid connections. Interconnectors are continuing to be built in Europe and North America, and they are rational economically for Japan as well, but there is still little momentum in Japan toward their construction. The underlying reasons for this were found to be a lack of adequate recognition of the diverse socioeconomic ripple effects and, in particular, psychological concerns related to energy security. These findings have been compiled in this Third Report.

Chapter 1 outlines developments in international grid connections over the past year in Northeast Asia. With renewable energy being progressively deployed in China, South Korea and Taiwan as well, China and South Korea have a bilateral agreement and are moving forward on interconnector construction. In Japan, there have been discussions on enhancing inter-regional transmission lines since the major power blackout in Hokkaido in September 2018.

Chapter 2 introduces international grid connection initiatives in the UK and Spain based on the Study Group's field survey of the two countries. The UK is an island nation like Japan and historically only had a limited number of interconnectors, but in recent years, submarine transmission lines with countries like Belgium and Norway have been built. Spain is at the Southwestern edge of continental Europe and except for Portugal, with which grid operations are integrated, the country only had limited interconnectors due to its unfavorable geography as a peninsula. To counter this, the country's transmission system operator (TSO) worked to integrate renewables to power systems through subtle grid operations that incorporated precise weather forecasts.

Chapter 3 considers in detail the benefit portion of the cost-benefit analysis of international grid connections the Study Group began in the second term. International grid connections are not only profitable for business providers; they bring diverse socioeconomic benefits to a wide range of areas. Assuming a specific route between Japan and South Korea, the chapter comprehensively analyzes, based in part on case studies, the impact of international grid connection on market competition, supply stability, climate change and other areas from the perspective of the various stakeholders involved along with the processes through which they are impacted.

Chapter 4 summarizes points of debate regarding international grid connections and energy security. Concerns over power exports being stopped for political reasons is one of the underlying reasons for the lack of discussion on international grid connections in Japan. International grid connections, however, as discussed in Chapter 3, are actually a means to securing supply stability internationally and help increase renewable energy, a purely domestic product, which is how they are commonly viewed in Europe and North America. At the same time, there have been cases of exports of natural gas and electric power being unilaterally stopped, so this possibility and measures to address it are also considered.

Chapter 1: Recent developments in Northeast Asia and Japan

The situation of Northeast Asia has been changing substantially in the wake of the dramatic change in the political situation on the Korean Peninsula in 2018. The same is the case for renewable energy growth and international grid initiatives. This chapter reviews related developments inside and outside Japan since the release of the Second Report, which is from around 2018 to June 2019.

Section 1: International grid initiatives in Northeast Asia

1) Renewable energy growth and the need for interconnectors

Renewable energy costs are coming down globally and its growth is accelerating. There are no signs of these trends dissipating, renewables continue to drive the energy transition in Northeast Asia. The following reviews the situation in South Korea, China and Japan where renewable energy is being expanded.

South Korea: The Moon Jae-in administration, which came to power in 2017, has set a national energy policy of phasing-out nuclear and coal-fired power and of maximizing growth in renewables with the recognition that international grid connections will be utilized. The country's Renewable Energy 3020 Plan released in December 2017 sets the target of raising renewable energy's share of the power supply from its current level of around 8% to 10.5% by 2022 and 20% by 2030. It proposes a policy of promoting solar photovoltaic (PV) and wind power in particular (Lee, 2019). South Korea's third energy master plan announced in June 2019 sets a new target of raising renewable energy's share to 30-35% by 2040 (MOTIE, 2019).

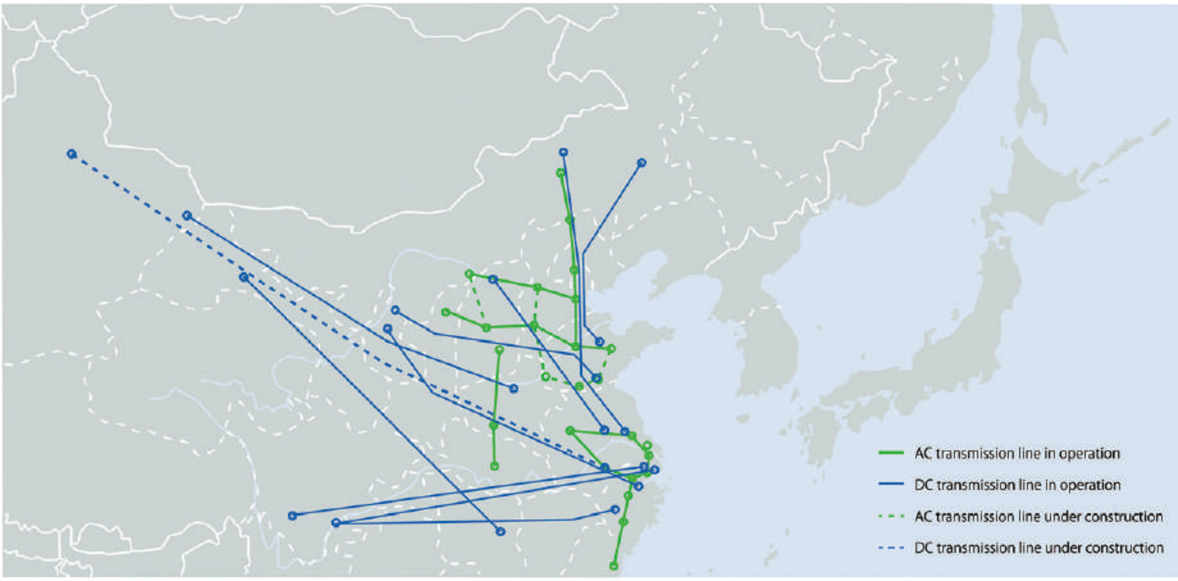
China: Renewables continue to expand in China. China's 13th Five-Year Plan on Energy Development and 13th Five-Year Renewable Energy Development Plan released in 2016 target the deployment of 380 GW of hydropower, 210 GW of wind power, 105 GW of solar PV, and 15 GW of bioenergy by 2020 (Table 1). In fact, as of the end of 2018, installed capacity of renewables increased by 12% year-on-year to 729 GW, 38.4% of the total. Hydropower stands at 352 GW, wind power at 184 GW, solar PV at 175 GW, and bioenergy at 18 GW; solar PV and bioenergy have already achieved their 2020 targets. Renewable energy generation increased 169 TWh from the previous year to 1,867 TWh, accounting for 26.7% of the total (NEA, 2018 and 2019. Installed capacity and electricity generated are rounded to the nearest whole number). Preparing for further large-scale deployment, the State Grid Corporation of China (SGCC) is currently constructing and operating total 32,000 kilometers of ultra-high voltage transmission lines in 22 projects (Figure 1).

Table 1: China's renewable energy deployment targets and results

	Installed capacity in 2020 (target) (GW)	Installed capacity in 2018 (GW)	Electricity generation in 2018 (TWh)
Hydropower	380	352	1,233
Wind	210	184	366
Solar PV	105	175	178
Bioenergy	15	18	91
Total	710	729	1,867

Source: Renewable Energy Institute based on National Development and Reform Commission and National Energy Administration (2016a, 2016b), and National Energy Administration (2019)

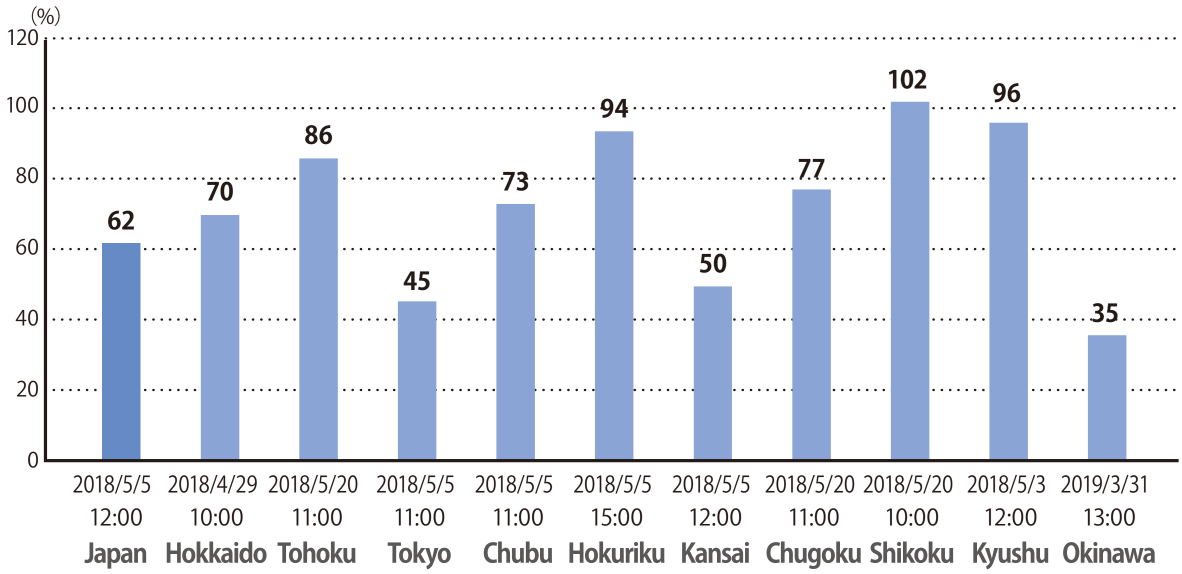
Figure 1: China: SGCC's domestic ultra-high voltage transmission projects



Source: Partially adapted by Renewable Energy Institute from SGCC (2019)

Japan: Installed capacity in 2018 included 6.5 GW of solar PV, for a cumulative total of 55.5 GW, and 261 MW of wind power, for a total of 3.6 GW (IRENA, 2019b). Growth in onshore wind installations has slowed, but with the Renewable Energy Sea Area Utilization Act (Act of Promoting Utilization of Sea Areas in Development of Power Generation Facilities Using Maritime Renewable Energy Resources) going into effect on 1 April 2019, Japan is poised to move forward with further deployment of offshore wind power, with related power grids expected to be enhanced and onshore wind power to expand. As solar PV increases, within Japan's regional service areas, there are periods of time when renewables share of the power supply temporarily rises to a high level (Figure 2).

Figure 2: Highest hourly renewable energy shares and time slots that were recorded in service areas across Japan (FY2018)



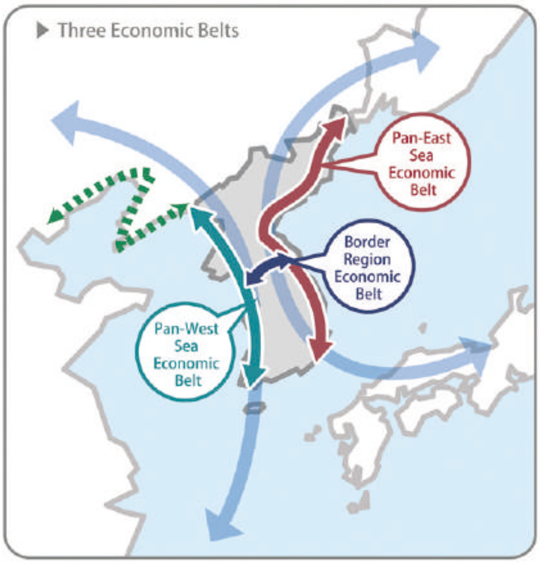
Source: Renewable Energy Institute based on data released by the general electricity transmission and distribution utilities

2) Changing political situation of Korean Peninsula and specific discussion of interconnectors

The political situation on the Korean Peninsula has been changing since the second half of 2017, and while there have also been setbacks, talks have commenced between North Korea and the United States (the US). In 2018 in particular, summit meetings took place multiple times between North Korea and South Korea's leaders, and agreement was reached on cooperating economically. In parallel with this, President Moon is actively pursuing a diplomatic agenda aimed at the economic integration of the Korean Peninsula, and in summit meetings with the US, Russia and China, he has vocally called for cooperation and understanding with respect to reducing political tensions on the peninsula. On his visit to Russia in June 2018, President Moon stated that if Russian natural gas and electricity were supplied to North Korea, South Korea and Japan, a road would open to promoting mutual prosperity in Eurasia; an agreement was reached with President Putin and a joint statement issued on promoting cooperation in developing gas pipelines, railroads and other infrastructure across the Korean Peninsula (The Kremlin, 2018).

For the South Korean government, the economic integration of the Korean Peninsula can be a first step toward securing direct routes with China and Russia and accessing a major economic zone. Regarding energy cooperation in particular, there are substantial expectations for development and expansion of renewables and construction of interconnectors. As this dialogue on economic cooperation deepens, construction plans for an international submarine transmission route between China and South Korea are expected to accelerate.

Figure 3: Moon Administration plan

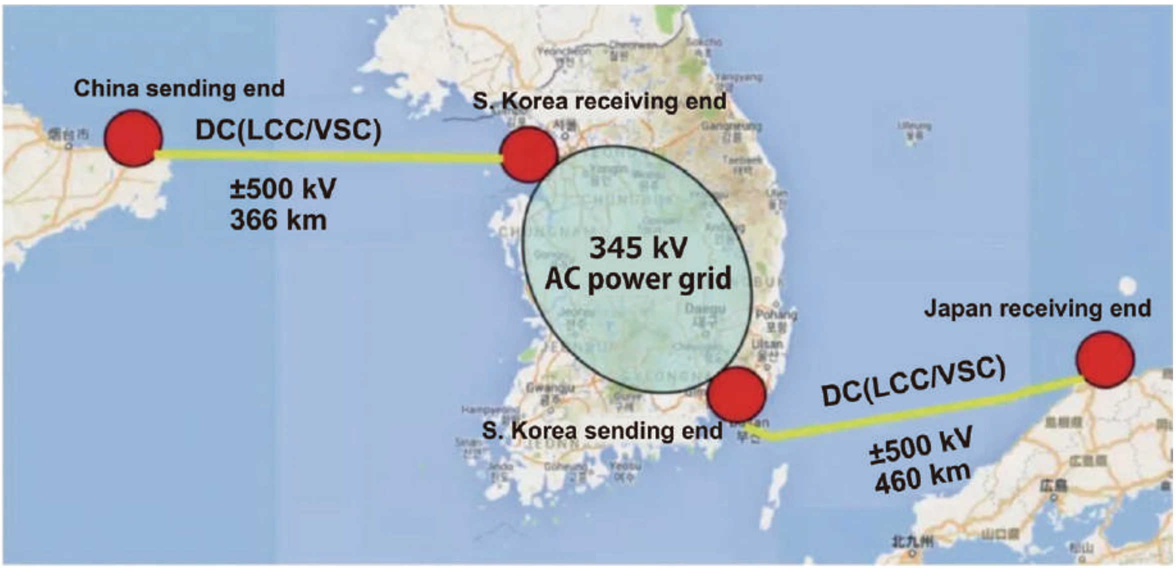


Source: Extracted from the Ministry of Unification (n.d., p. 24)

3) Progress on Japan-China-South Korea international transmission project

Cooperative efforts are proceeding at the research and project levels. In 2016, companies from Japan, China, South Korea and Russia agreed to research and plan international grid connections and are making various preparations toward the project stage. Beginning in December 2017, SGCC, Korea Electric Power Corporation (KEPCO), and the Global Energy Interconnection Development and Cooperation Organization (GEIDCO) led a joint China-South Korea project study on international grid projects. This joint study looked at project proposals for international grid connections between Japan, China and South Korea, verified technical feasibility and assessed costs and benefits. In the research report issued by GEIDCO (Yu, et al., 2018), one project proposal envisions an interconnector from Shandong province in China through the Incheon region in South Korea to Matsue in Japan (Figure 4). The proposed China-South Korea route is approximately 366 kilometers, and the Japan-South Korea route, approximately 460 kilometers. The interconnector's optimal capacity and voltage are set at 2 GW and 500 kV DC based on the current level of submarine transmission line technology and existing transmission line specifications in the three countries. The results of this analysis estimated the transmission cost at approximately 0.038-0.066 USD/kWh (Table 2). In addition, based on the assumption that a mix of wind power (60%) and thermal power will be transmitted from China, the power generation cost in China is estimated at approximately 0.08 USD/kWh, and if the annual electricity transfer to Japan is 10 TWh or more, electricity charges on the receiving end in Japan, including transmission charges, would be less than the domestic generation cost with fossil fuels (coal- and gas-fired plants), so the study concludes that the project would be economically viable.

Figure 4: Sketch of the China-Korea-Japan interconnection project



Source: Partially adapted by Renewable Energy Institute from Yu, et al. (2018), Figure 1

Table 2: Transmission cost for Japan-China- South Korea interconnector

Annual electricity transported (TWh)	**Usage time** (h)	**Transmission cost** (USD/kWh)		
		Plan (1)	**Plan (2)**	**Plan (3)**
10.5	5,200	0.0534	0.0662	0.0626
12.3	6,100	0.0469	0.0579	0.0548
14.0	7,000	0.0421	0.0517	0.0490
15.8	7,800	0.0383	0.0468	0.0444

Note: Plans (1), (2) and (3) are based on Yu, et al. (2018) and have different transmission formats and main circuit configurations. Estimates assume use of XLPE transmission cable.

Source: Renewable Energy Institute based on Yu, et al. (2018), Table 7

Section 2: Power system reform in Japan

With considering installation of interconnectors between Japan and other countries, it is important for Japan to make further progress in reforming its domestic power system. This is because the domestic market stands to develop competitively and the potential for power market expansion increases due to interconnectors.

Full-fledged debate on reforming the power system in Japan began after the Great East Japan Earthquake and the nuclear accident at Tokyo Electric Power Co. (TEPCO)'s Fukushima Daiichi Nuclear Power Plant in 2011. In 2015, the Organization for Cross-regional Coordination of Transmission Operators (OCCTO), which operates transmission grids divided by region on a cross-regional basis, and the Electricity Market Surveillance Commission (now the Electricity and Gas Market Surveillance Commission, EGC), which oversees the market, were established. In 2016, full liberalization of the retail power market commenced. In 2020, the legal unbundling of generation and transmission by the former general electricity utilities (hereinafter, "major power utilities") is planned. The legal unbundling has already been done for TEPCO in 2016, with its transmission and distribution division spun off into a separate company (TEPCO Power Grid), and the other major power utilities have begun to prepare by establishing companies for the same purpose.

1) Progress in electricity markets

Three years have passed since liberalization of the retail electricity market, and PPS (Power Producer and Supplier) now accounts for approximately 15% of electricity market supply as of March 2019 (Agency for Natural Resources and Energy, 2019b). Over 580 PPS have been registered to date (ibid.).

Base load market: At the same time, major power utilities and their subsidiaries are utilizing their ample supply capacity to remain competitive in the market. Given these circumstances, in July 2019, a "base load market" was introduced as a measure to increase the access of PPS to power plants and stimulate the wholesale electricity market. In Japan, "base load" power sources are mainly nuclear, coal-fired, and large-scale hydropower, and most are owned by the major power utilities or selling to them on long-term contracts. Those are mainly large-scale power plants built using the fully distributed cost approach before liberalization, and the power they now supply is sold at low prices on the market. There is the potential for a lack of flexibility in grid operations, if electricity from those big power plants are under fixed transactions in "base load market." The first auction was held in August 2019 and resulted in underperformance transaction.

Capacity market: A capacity market is also planned for 2020. With the liberalization of retail power and increased deployment of renewables, wholesale electricity market transactions increases and market prices decreases, and there are concerns emerging that investment in power sources becomes harder to predict. The electricity itself will be traded on the normal wholesale electricity market, but this system will allow power capacity (kW) that will be procured in the future to be bought and sold in advance. In general, all power sources will be subject to the system, and there are concerns that it will be a rescue measure for existing large-scale power plants.

Non-fossil fuel energy value trading market: Since the non-fossil fuel energy value trading market began in May 2018, "non-fossil fuel energy certificates for FiT renewables," those for renewables supported under the feed-in tariff (FiT) scheme, are traded. The current market is very sluggish, but in 2020, there are plans to expand the scope to include non-fossil fuel energy certificate to large-scale hydropower, nuclear power and non-FiT renewables.

There are concerns that introducing these various market mechanisms will create too much complexity in the power market and that this would not be consistent with the goal of establishing a flexible, efficient power system. The markets need to be planned carefully to prevent any discrepancies from developing between the government's energy policy and the future power market.

2) Enhancing cross-regional transmission operations and grid systems

Approaches to inter-regional transmission operations and grid connections are being reconsidered. Regarding cross-regional transmission lines, the previous first-come-first-served rule, which was a cause of inefficient operations because it fixed over the long term the power sources that could be used, was changed in October 2018 to implicit auction. Cross-regional transmission lines are now assigned via the Japan Electric Power Exchange (JEPX) spot market so that providers with the lowest costs can utilize them according to merit order. The implicit auction has already started and has been effective in increasing spot contract volume.

Changes are also taking place in Japan's power market due to the increase in renewables, such as lower prices during peak demand. Increasing flexibility through maximum use of existing transmission systems to be able to accommodate variable renewables, which will continue to increase into the future, is an urgent necessity. This means not only introducing interconnectors but also considering fairly the cross-regionalization of Japan's transmission operators themselves and introducing unbundling of the distribution system operators (DSO).

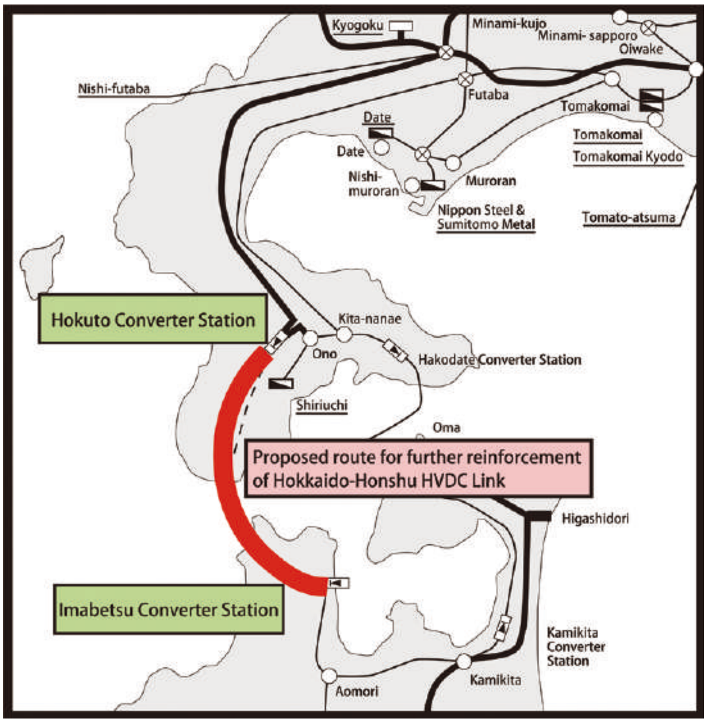
Debate on cross-regional transmission enhancement and cost sharing

Debate has begun on cross-regional transmission enhancement. One proposal is for the cost of this enhancement to generally be borne nationally. With regard to enhancing transmission lines in connection with the benefits of renewables in particular, sharing costs nationally via a similar system to FiT surcharges is considered (Agency for Natural Resources and Energy, 2019a). Enhancing transmission lines will contribute to increased distribution of renewable power on a nationwide scale, not just in the region where the facilities are located, and the costs therefore should be borne nationally. At the same time, regarding the way costs would be covered, the basic approach would be to allocate profits obtained through regular transmission operations, including regulated grid tariffs, based on the central government's medium-to-long-term plan for power grid construction. Regardless of the method used to collect charges, it is essential that the process be transparent, with assessments conducted on the validity of benefits generated by enhancement, close scrutiny of how projects are prioritized in terms of construction schedules, disclosure of cost breakdowns, and the like.

The Hokkaido Eastern Iburi Earthquake, which struck on 6 September 2018, caused a large-scale power outage across all of Hokkaido. It was Japan's first blackout. According to the explanation from OCCTO, the blackout was primarily caused by the stoppage of Tomato-Atsuma Coal-fired Power Plant 1, 2 and 4 and the stoppage of hydropower caused by an accident on the Karikachi Trunk Line and two other lines (four transmission lines) caused by the earthquake, so a combination of factors (N-3 + N-4) were responsible (OCCTO, 2018d). Putting aside the advisability of relying on power generated at one site (Tomato-Atsuma Thermal Power) to supply half of the prefecture, if Hokkaido enhanced its system for receiving electricity from outside sources in case of emergency, complete blackouts like this could be prevented.

From out of this turn of events, a proposal was promptly made to further enhance the Hokkaido-Honshu HVDC Link transmission line. It can be assumed that the above-mentioned nationwide cost-sharing rules for cross-regional transmission lines will apply to enhancement of this line (Proposed route for further enhancement of Hokkaido-Honshu HVDC Link). Hokkaido-Honshu HVDC Link was enhanced by 300 MW (0.3 GW) in March 2019, increasing capacity to 900 MW (0.9 GW), and this time, in 2026, capacity will be enhanced by another 300 MW (0.3 GW) primarily in order to increase deployment of renewables (Figure 5). Enhancement of domestic transmission system is one of the preconditions for introducing interconnectors, but the proposal itself for a Japan-Russia interconnector route via Hokkaido would clearly contribute to further stabilizing the electricity supply in Hokkaido. To ensure the power grid is efficiently optimized as a whole and not just in parts, it is imperative that a master plan be drawn up that outlines an ideal power grid system for Japan in 2030 and 2050.

Figure 5: Proposed Route for Further Enhancement of Hokkaido-Honshu HVDC Link



Source: Extracted from OCCTO (2019a, p. 22)

3) Operation policy for integrating renewable energy into the grid

Introduction of the Japanese version of "Connect and Manage"

The Japanese version of "Connect and Manage" has started to be applied for renewables with the goal of full-fledged deployment by 2022. Previously, when it was necessary to enhance the grid to connect renewables, the connection could not be made until enhancement work had been finished. Utilizing Japanese version of Connect and Manage though allows the "connection" to be made before the work is completed. However, with regard to grid "management," it assumes that in the case of failure or a surge of power on the grid, balancing capacity of power flows would involve curtailing the generating facilities to be connected to the grid in the future, rather than curtailing from facilities that are already connected.

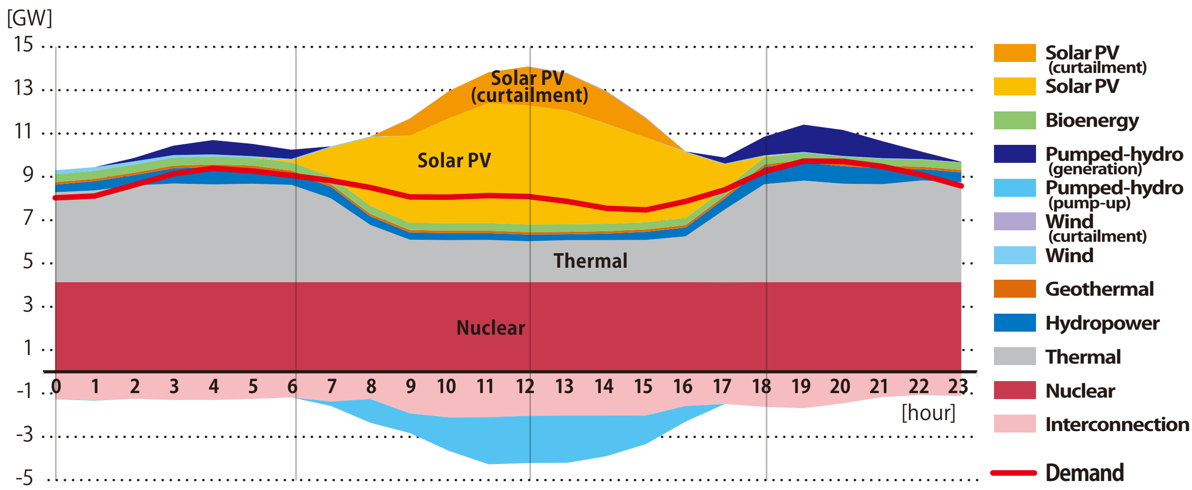
As a result, this approach risks limiting the grid's balancing capacity or imposing excessive curtailment exclusively on newly connecting facilities. In Germany and the UK, where they have already adopted a similar scheme, balancing capacity of power flows is also required of already-connected generating facilities in a more flexible and economical manner. The Japanese version should also include existing generating facilities in the scope of its power flow control. Furthermore, any future mechanism designed with interconnectors in mind should avoid treating existing and new generating facilities differently, and should instead enable electricity to be used efficiently in each time slot.

Curtailment of renewable electricity

In the Kyushu area, where nuclear power is being put back into operation, solar PV and wind power, are being curtailed, due to the rule that renewables supply priority is lower than that of nuclear. This exercise by Kyushu Electric Co. is afraid to bring major power utilities in other regions to follow suit. Figure 6 is an example of the supply-demand balance (curtailment) based on records released by Kyushu Electric (March 24, 2019). Cross-regional transmission line and pumped-storage hydropower are also being used, and it can be seen that nuclear power is supplying electricity in stable, fixed amounts. Depending on the various market deployments and government policies discussed above, it is possible that nuclear power operations will be resumed to a certain extent in other areas as well, possible competition in terms of grid operation may occur with inflexible nuclear power and increasing variable renewable power sources. Renewable energy is a power source with close to zero marginal costs and should be traded first (merit order); the market system needs to be redesigned, and this includes revisions to Japan's unique "priority dispatch rules."

As already proposed in the Study Group's Second Report, if there is an interconnector with Kyushu area and other countries, it would greatly contribute to reducing the curtailment. With regard to the construction and enhancement of transmission systems within Japan as well, a new cross-regional transmission line connecting the Kyushu and the Shikoku area as proposed in the report would no doubt be worth considering as a means to supply the Kansai area, a major power consumer, with electricity from Kyushu, where supply is in surplus, through the Shikou area.

Figure 6: Supply and demand balance in the Kyushu Area (24 March 2019)



Source: Renewable Energy Institute based on data released by Kyushu Electric Power

Chapter 2:
International grid initiatives in the UK and Spain

This chapter reports the findings of a field survey on interconnections in the UK and Spain conducted by the Study Group in the fall of 2018. The Study Group visited progressive areas of Europe; Belgium, Norway and Sweden in 2016, and the US and Canada in 2017, and in both cases found that for a variety of reasons interconnectors were being built and utilized. Compared to these cases, the UK is an island country like Japan, and Spain is located on the Iberian Peninsula on the westernmost side of continental Europe. Geographically, conditions are not favorable for interconnections, but in spite of this, both countries continue to increase variable renewable energy. The two countries are relatively similar to Japan in terms of the conditions they face, and in this chapter the report clarifies how the countries are approaching international grid connections and renewables.

Section 1: Basic information on electricity in the UK and Spain

Table 3 provides basic information on electricity in the UK and Spain. Total electricity generation in both countries is about equivalent, and is roughly 30% of Japan’s[1] . Spain’s power mix includes 13.7% hydropower, 18.8% wind power, and 4.6% solar (including CSP); it boasts one of the highest renewable energy rates in the world. The UK has minimal hydropower but wind accounts for 17.9%, solar PV for 4.0% and biomass for 10.7%. Its development of offshore wind power in recent years is particularly noteworthy. Nuclear power accounts for around 20% as well, but the UK, a gas producer, has a particularly high rate of gas-fired power.

Table 3: Basic electricity information in the UK and Spain (2018)

(TWh)	UK	Spain
Total electricity generation	319.7	263.3
Hydropower	7.9 (2.5%)	36.1 (13.7%)
Wind	57.1 (17.9%)	49.6 (18.8%)
Solar PV*	12.9 (4.0%)	12.2 (4.6%)
Biomass	34.1 (10.7%)	5.9 (2.3%)
Nuclear	59.1 (18.5%)	53.2 (20.2%)
Coal	16.8 (5.3%)	37.4 (14.2%)
Gas	125.8 (39.4%)	54.3 (20.6%)
Installed capacity	104GW (2017) Wind 22GW, Solar 13GW	104GW Wind 23GW, Solar*7GW
Imports	Total 21.3 France 13.3, Netherlands 6.4, Ireland 1.7	Total 24 France 15.5, Portugal 8.3
Exports	Total 2.2 Ireland 1.6, France 0.4	Total 12.9 Portugal 5.7, Morocco 3.6, France 3.5

Note*: Solar in Spain includes CSP

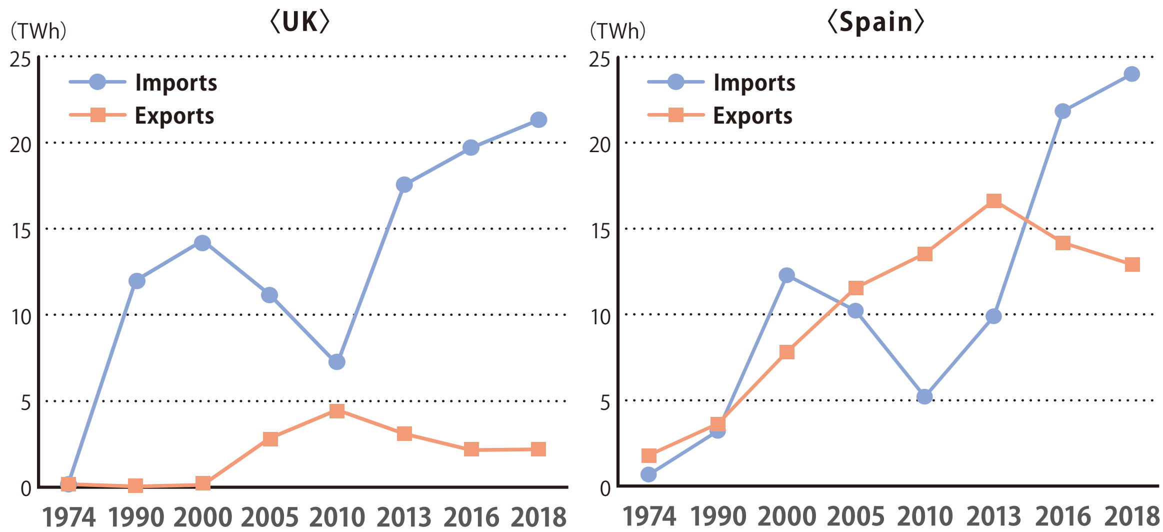
Source: Renewable Energy Institute based on IEA (2019b), BEIS (2018), BEIS (2019), REE (2019b)

1 Spain’s total electricity generation is about the same as the amount of power generated and consumed in the TEPCO service area (total generated by TEPCO and received by other companies was 260.5 TWh in FY2015) (TEPCO, n.d.).

From the standpoint of power system reform, liberalization measures taken by the two countries, such as unbundling generation and transmission, were completed some 30 years prior, and they have entered the stage of actively moving forward with incorporating renewable energy. Spain divided ownership in 1985, the earliest country in the world to do so, and established Red Eléctrica de España (REE) as the TSO. The UK is one of first countries to work on power market reform, establishing National Grid as its TSO in 1990. There is nothing inhibiting competition with respect to grid connection, and both TSOs are proactive about deployment of renewable energy.

International trade of electricity has generally been increasing in both coutnries. Figure 7 shows historical trends, and while there are differences depending on the year, Spain in recent years has imported approximately 4-9% of its electricity generated and exported 4-6%. Most exports are to Portugal and Morocco, and most imports are from France and Portugal. The UK basically imports more than it exports, and its exports are minimal. Wholesale electricity prices in the UK are relatively high compared to continental Europe, so it has consistently imported 5-7% of its total electricity generated from other European countries.

Figure 7: Electricity exports and imports in the UK and Spain



Source: Renewable Energy Institute based on IEA (2018), IEA (2019a), IEA (2019b)

Section 2: UK's development of offshore wind power and enhancement of interconnectors

1) Development of offshore wind power

The UK is the world's largest producer of offshore wind power. According to WindEurope (2019), Europe's installed capacity for offshore wind power in 2018 was 18.5 GW, and the UK at 8.2 GW accounted for nearly half of that total. Offshore wind power accounts for approximately 10% of wind power in Europe as a whole, but at 40% its share is much higher in the UK. One factor lying behind this is the government's active promotion of offshore wind power over the past 15 years in response to community concerns over the siting of onshore wind farms. For example, the government demarcating waters for offshore development with the involvement of the British Monarch's Crown Estate and the establishment of a legal framework for facility construction are both noteworthy initiatives.

Infrastructure for offshore transmission is indispensable to offshore wind power, and in 2009, a system has been introduced in which offshore transmission providers are designated through competitive bidding that is separate from the onshore power grid which National Grid is responsible for. Submarine transmission lines for offshore wind power are often built by the wind power provider, but a mechanism has been established by which they are owned by financial institutions and operations are conducted by National Grid from a neutral position. Offshore wind power providers are therefore able to invest in power projects without concerns about connecting to the grid.

The UK government also participates in the Powering Past Coal Alliance and has a goal of eliminating coal-fired power by 2025. So, in recent years, it has greatly reduced coal-fired power and plans to continue eliminating coal as a power source by increasing deployment of renewables and building and planning to expand nuclear power. However, regarding nuclear power, there continues to be examples of projects coming to a standstill due to uncertainty over investment recovery, and in January 2019 it was announced that the Horizon project promoted by Hitachi was being suspended (Hitachi, 2019), which was widely reported in Japan as well. These circumstances are impacting the format of the interconnectors as stated below.

Regarding the impact of Brexit, currently a major issue in the UK, we posed the question at places we visited, and most people indicated that the impact is unknown. The unclear trajectory of Brexit itself is likely the major reason for this, but since it entails leaving the large market of Europe, it is hardly likely that the impact will be positive in terms of electricity market integration and international trade. Being removed from the spot market's market coupling was even pointed out as a possibility.

2)Interconnector enhancement in recent years and "cap and floor"

Due in part to the UK being an island nation, it has not historically depended on interconnectors. The IFA interconnector (160 MW) with France was built in 1961 and enhanced to 2 GW in 1986, but for a long period of time this was the country's only interconnector. Except for the Moyle submarine transmission line (0.5 GW) with Northern Ireland, which is part of the UK that went into operation in 2001, there had been no new construction until 2010. In interviews, we were told the main reason was the technological and economic difficulty of long-distance submarine transmission cables.

However, since the 2000s, partly as a response to climate change, the country revamped its energy policy, and based in part on the policies of the European Commission, it began to place importance on interconnectors, and has been building them in recent years. The BritNed connector (1 GW) with the Netherlands went online in 2011 and the EWIC connector (0.5 GW) with Ireland, in 2012. Combined, the transmission capacity of the UK's interconnectors has reached 4 GW as of the end of 2018 (Figure 8).

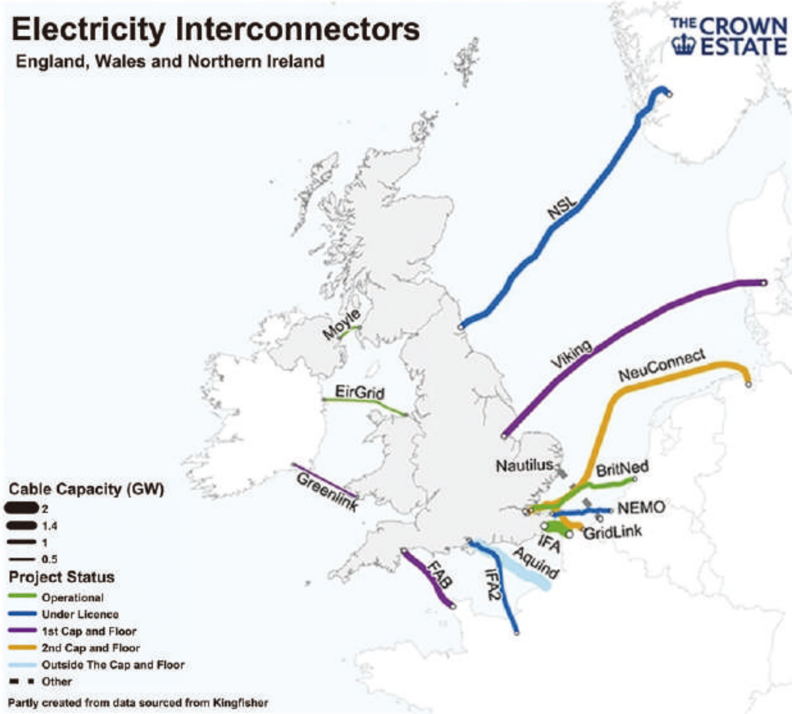
Thereafter, Nemo Link (1 GW) with Belgium was completed in January 2019. Even now, IFA2 (1 GW) and ElecLink (1 GW) with France and North Sea Link (1.4 GW) with Norway[2] are under construction. In addition, FAB Link (1.4 GW) with France, Viking Link (1.4 GW) with Denmark, and NeuConnect (1.4 GW) with Germany, among others, are being planned[3]. When these are completed within the next several years, it is expected to increase the installed capacity of the UK's interconnectors by three times.

2 North Sea Link will have a total length of 740 kilometers, eclipsing the 580-kilometer NorNed for the longest interconnector in the world.

3 For details on the UK's interconnectors, including those in the planning stage, refer to Ofgem (2019).

We asked the policy official in charge why the UK has been able to build so many interconnectors in recent years, and the answer was extremely interesting; we were told that interconnectors are one of the few investments to fulfill the 3 Es[4]. As discussed above, there are price differences with continental Europe, so trading electricity through international grid connections is economically rational. In addition, as offshore wind power in places like the North Sea increases, the possibilities for international grid connection increase as well. That this runs counter to Brexit is ironic, but at the very least in the area of electric power, the UK has been strongly oriented toward integrating its market with Europe. The country's work to enhance its interconnectors is emblematic of this.

Figure 8: Map of electricity interconnectors in the UK



Source: Extracted from the Crown Estate (2018)

"Cap and floor," which was instituted in 2014, is one of the policy measures that has supported this. In the UK, National Grid, which is responsible for the country's domestic transmission grid, is not responsible for its interconnectors, but each project is required a separate project license. The country has established a quasi-regulatory fee system as a mechanism for recovering investment on interconnectors whereby interconnector revenue in excess of a preset limit (cap) is returned to consumers and revenue below the lower limit (floor) is supplemented, with consumers shouldering the cost. The program as a result has succeeded in balancing cost control against the certainty of investment recovery, and in interviews with the UK government, it was emphasized that this was one factor for the spate of new interconnectors built in recent years.

Section 3:
Spain's progressive grid operations and international grid systems

1)Deployment of renewable energy and REE grid operations

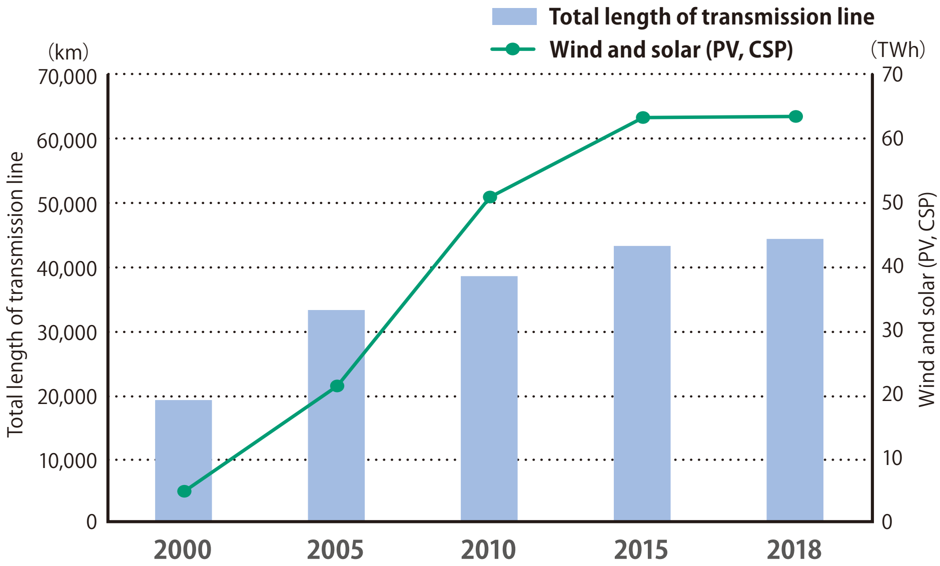
As mentioned above, Spain utilizes large amounts of renewable energy. The country significantly increased its variable renewables (solar PV and wind power) in the 2000s through a feed-in tariff

4 The three Es of energy policy are; energy security, economic efficiency and environment.

scheme (FiT). However, due to deficiencies in the design of the scheme, the global financial crisis of 2008, and other factors, it retroactively stopped the FiT scheme as the country's economy slowed, and growth in renewables stagnated.

At the same time, the precise grid operations of REE, which fully integrated into Spain's grid the rapid increase in renewable energy (Figure 9), is particularly noteworthy. In Spain, where variable renewables increased from the first half of the 2000s, REE continuously enhanced the domestic power grids (Figure 9) and implemented reforms to the power system that were favorable to renewable energy, including establishing the Control Centre of Renewable Energies (CECRE), the department responsible for issuing load dispatch instructions exclusively for renewable energy, raising the precision of weather forecasts, and conducting balancing capacity and controls for all power sources in a rational manner[5]. Moreover, with the cooperation of major wind power providers like Iberdrola, a system has been created that allows for remote, centralized control. As a result, curtailment of renewable electricity is kept to the same or lower levels than other European countries despite Spain's relative lack of interconnectors[6]. Japan is said to be disadvantaged geographically as well, but there is much it can do to allow for the large-scale deployment of renewables domestically.

Figure 9: Spain's Grid Enhancements and Wind/Solar (PV, CSP) Electricity Generated



Source: Renewable Energy Institute based on REE (2001, 2006, 2011), REE (2016), REE (2019b), BP (2019)

In the midst of these developments, Spain's government changed hands in June 2018 and the Pedro Sanchez administration, proactive with respect to renewable energy, gained power. The country's Ministry of Agriculture and Fisheries, Food and Environment was reorganized into the Ministry for the Ecological Transition and a target was set of 100% renewable power by 2050, as the new government has taken a proactive stance toward the energy transition. In 2019, new wind power projects of 4 GW are expected and Spain is garnering renewed attention for renewables (Energy Reporters, 2019).

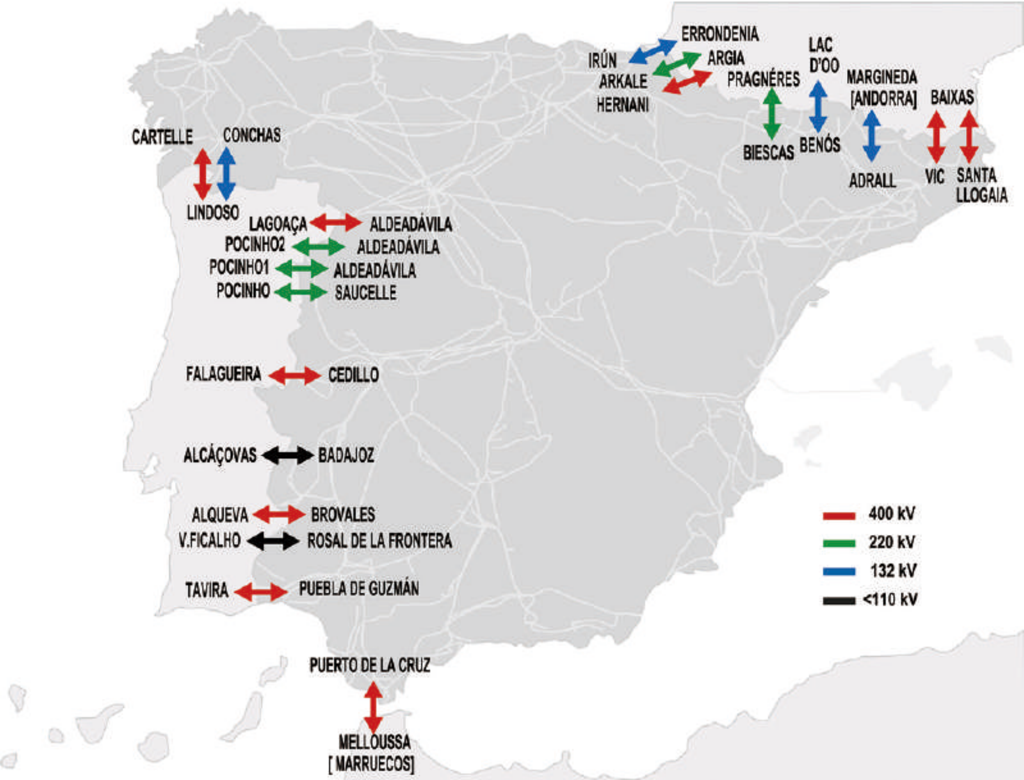
5 At REE, all power generating facilities over 10 MW must be directly controlled by CECRE. CECRE uses a monitoring and control system called GEMAS to measure and analyze in real time power output and grid information every 20 minutes, calculate maximum power output at each wind farm, send control signals to renewable energy facilities and if necessary, conduct curtailment. Regarding the output prediction system as well, predictions are made in one-hour intervals for the upcoming 48 hours and prediction values are updated every 15 minutes. The prediction margin of error is low, within the range of 2-3% (rated output basis), and instructions for wind power output are prepared sequentially to address output shortages and surpluses.

6 According to the Associación Empresarial Eólica (AEE), Spain's wind industry association, and REE, the curtailment rate was high (approx. 2.13%) only in 2013; since then, in most years, it has been less than 1%. Solar PV is almost never curtailed. Refer to AEE (2013-2018), AEE (2019), REE (2018).

2) Present and future of Spain's international grid connections

International grid connections are naturally important to Spain. The country has established multiple interconnectors with Portugal in particular (Figure 10), a total of 3.4 GW in the export direction and 2.3 GW in the import direction, and their power markets have been integrated into one market and operations integrated as well. With Morocco, also, Spain has submarine transmission lines, 0.9 GW export and 0.6 GW import, and the two countries agreed in February 2019 to build another 0.7 GW line[7]. At present, exports to Morocco exceed imports, but going forward, there is an increasing possibility that low-cost solar and other power will be imported.

Figure 10: Map of current international electricity interconnections on the Iberian Peninsula



Source: Extracted from REE (n.d.)

On the other hand, overall, Spain has only a limited number of international grid connections by European standards. The key to their expansion is interconnectors with France, which could connect the country into the large market of continental Europe, but presently such connections are limited to 2.8 GW in the export direction and 3.4 GW in the import direction. Planning, investment and ownership of these interconnectors have been conducted either by the TSOs of Spain and France separately, or by a joint venture established by the two entities. The European Commission targets require member countries to establish interconnectors at 10% of domestic installed capacity by 2020 and at 15% by 2030 (European Commission, 2017), but Spain currently stands at less than 5%, so meeting the target by 2020 will be difficult.

It will need to increase its interconnectors going forward, and as of June 2019, it is currently planning to build submarine transmission lines to France (two 1 GW lines) via the Bay of Biscay. Based on interviews, an interconnector through the Pyrenees would be too difficult from an environmental protection standpoint and diplomatic calculations in France are also a factor (France would prefer not to import more electricity). Be that as it may, Spain still has ample opportunity to expand its international grid connections going forward.

7 Total investment is 150 million euros, which according to plans will be divided equally between the two countries. Refer to REF (2019a).

Chapter 3:
Cost-benefit analysis of international grid connections

This chapter outlines an approach to cost-benefit analysis for new installations and expansion of interconnectors, and then discusses the potential benefits and deficits of interconnectors between Japan and neighboring countries in relation to different stakeholders. Section 1 provides an overview of cost-benefit analysis in other countries and organizes the benefits found in these prior studies. Section 2 clarifies the process by which international grid connections generate these benefits. Following this, Section 3 specifically discusses how benefits are generated using as an example one of the proposed routes of the Japan-South Korea interconnector taken up in the Second Report. Finally, Section 4 analyzes the involvement of stakeholders related to phenomena constituting the benefit generation process.

Section 1: Approaches to the benefits of international grid connections

1) Characteristics of benefit analysis for international grid connections

Cost-benefit analysis is the comparative evaluation method of the costs of implementing a project and the benefits the project delivers to society, and it is conducted as a part of the process for making decisions on social infrastructure investment and the like. In general, when costs are borne by the central government or local governments, the scope of the benefits is set within the range of those bodies. However, when cost-benefit analysis is conducted for cross-border projects, for example, when multiple countries invest and receive the benefits or when projects span multiple regions who profit differently from the project, there are aspects that differ from deliberations made with typical social infrastructure development. One consideration is whether to assess only the economic benefits or to broadly consider other benefits as well.

Looking at cost-benefit analysis performed for typical social infrastructure projects and taking decisions made for transmission line enhancement, either domestically or within the same region, as an example, social welfare (the total surplus for society as a whole) are the main type of benefit assessed (OCCTO, 2016). In this case, the cost-bearers and beneficiaries are both located in the same area, so it becomes possible to conceive of the project for transmission line enhancement as economically rational for that area.

In cost analysis for international grid connections, however, social welfare (economic benefits) increases for the overall area where the transmission lines are built, but it is also possible that there will be countries, regions and companies economically disadvantaged by the project. When an interconnector spans two countries with differing wholesale electricity prices, the average wholesale electricity prices in the two countries joined by the interconnector will decline (benefits increase for the overall area), but the price in the country where electricity is cheaper will go up and the price in the other area will go down. It could be occurred that electricity charges go up in one country or region, high-cost power plants in the other country may close and jobs may be lost.

By contrast, setting the evaluation axis to include non-economic benefits that are emphasized by the countries being connected allows international grid connection projects to move forward positively when the benefits outweigh the disadvantages for the countries involved. When multiple non-economic benefits are considered, Country A may emphasize Benefit X and Country B may emphasize Benefit Y. This could lead deliberations to combine Countries A and B and conclude that benefits would increase overall. Typical examples of such deliberations performed from a medium-to-long-term perspective are the cost-benefit analyses conducted by the European

Network of Transmission System Operators for Electricity (ENTSO-E) and others. ENTSO-E's cost-benefit analysis seeks to determine the optimal network of international grid connections for Europe as a whole, taking the period from 2030 to 2050 as the scope of its evaluation, in order to integrate EU-wide energy markets and expand integration of renewable energy. The evaluation items include not only social welfare (economic benefits) and carbon dioxide (CO_2) reductions, but also, for example, the increase in adequacy and the impact on ecosystems and scenery. In Japan as well, a cost-benefit analysis has been considered that takes into account multiple evaluation axes beyond social welfare in order to plan cross-regional interconnectors for enhancement from a nationwide standpoint (OCCTO, 2018a). However, with the large-scale power outage incident in Hokkaido and other developments, as of the present, cost-benefit analysis has been limited to selecting the route and size of interconnectors over a specific narrow range, and evaluation items have been primarily economic benefits (OCCTO, 2019b).

Here we identify and organize the types of items considered as benefits (or costs) in the cost-benefit analyses of international grid connections conducted by other countries, including ENTSO-E. In cost-benefit analysis based on welfare economics, items that can be converted to a monetary value are called "benefits" and items that cannot be converted or are assessed in terms of non-monetary value are called "utility" or "effectiveness" but this study treats them all as benefits in the broad sense.

2) Prior cost-benefit analyses

ENTSO-E conducts cost-benefit analysis for enhancement of international grid connections Europe-wide as a part of its 10-year network development plan (TYNDP). The analysis is intended to clarify the characteristics of proposed transmission line and energy storage projects and provide helpful information to policymakers. This is backgrounded by Europe's efforts to integrate its energy markets and increase deployment of renewable energy, and international grid connections are positioned as the means to do so.

Benefit items are not limited to social welfare (consumer surplus and producer surplus); the analysis is characterized by the fact that it also considers CO_2 reductions and renewable energy deployment as well as the ancillary benefits of CO_2 reductions, the impact on ecosystems and scenery, and more. In addition, grid loss, adequacy, grid operations, voltage and frequency stability, and other items specific to electric power systems are also evaluated. The final results were released in 2018 in the TYNDP 2018 report. In Europe's case, it is possible to consider Europe-wide benefits as a single market, so while it is a cost-benefit analysis for international grid connections, there are aspects similar to cost-benefit analysis for the domestic projects of individual countries.

In the UK, the Office of Gas and Electricity Markets (Ofgem), a regulatory body, is responsible for licensing interconnector construction projects. Of these, Nemo Link, for which an interconnector license application was submitted in 2012, was considered as a model cap and floor project jointly by Ofgem and the Commissie voor de Regulering van de Elektriciteit en het Gas (CREG), Belgian regulatory body (Ofgem, 2014). The UK had, up to that time, used a business model in which investment recovery for interconnectors was conducted commercially, but the European Commission, since its Second Energy Package in 2003, had recommended adopting a business model based on regulated grid tariffs, and the cap and floor model corresponded to this (Asia International Grid Connection Study Group, 2017). After Nemo Link, it became possible for the cap and floor model to be applied to other interconnectors, which made possible the proposals for the various UK interconnection projects discussed in Chapter 2.

In such cases, Ofgem defines upper and lower limits for profit margins and conducts cost-benefit analysis in order to determine whether to license a project. The benefit items assessed are primarily social welfare for the UK and the partner country combined, and in addition to this, contribution to decarbonization is included in qualitative form. Like the cost-benefit analysis conducted by ENTSO-E, deliberations are conducted on items specific to electric power systems like balancing capacity and supply stability. Other cost-benefit analyses conducted recently include NorthConnect, NeuConnect and GridLink, which were released in 2017 (Ofgem, 2017). Behind the push in the UK to build interconnectors are the need to deploy renewable energy for decarbonization and the country's high wholesale electricity prices compared to continental Europe.

In Asia, the ASEAN Centre for Energy (ACE), GEIDCO, and the United Nations Economic and Social Commission for Asia and the Pacific (U.N. ESCAP) conducted a joint study on the benefits of increased deployment of renewable energy and regional integration of energy markets in the ASEAN region and published the findings in 2018 (ACE, et al., 2018). The study addresses both the issue of sustainable economic growth in the ASEAN region and the problem of climate change, and using a system dynamics approach, it organizes the series of phenomena caused by international grid connections and classifies them into social benefits, economic benefits, resource benefits and environmental benefits. The benefits are further subdivided into promotion of research and development, increased employment opportunities, a decrease in regions without electricity, improved standard of living, promotion of sustainable growth, better development, reduced development costs, increased energy supply flexibility, improved energy supply diversity, more efficient resource use, reduced CO_2 emissions, greater mitigation of climate change, and environmental protection, including ecosystems, and quantitative analysis is performed on some of the categories.

The cost-benefit analyses of ENTSO-E, Ofgem and ACE all have multifaceted evaluation items to help form consensus on the construction of international grid connections. Comparing the evaluation items of the three analyses (Table 4), in each case, given the current context after the Paris Agreement of 2015, expanded deployment of renewable energy and integration of energy markets (building international grid connections) are positioned as solutions to the problem of climate change. It is also worth noting that benefits other than economic benefits (social welfare and average generating costs) are defined separately, from CO_2 reductions effect to level of renewable energy deployment. CO_2 reductions are already evaluated as an economic benefit in the form of the carbon tax and renewable energy deployment in the form of electricity generation costs, so including these in other items is redundant. However, these items themselves are policy targets, so they are defined separately and evaluated. Phenomena specific to the region subject to the cost-benefit analysis are also considered as evaluation items. In ENTSO-E's case, these include reducing grid loss and the impact on ecosystems and scenery, and in ACE's case, the population without access to electricity, R&D investment, sulfur oxide (SOx)/ nitrogen oxide (NOx) reductions and others.

Based on these preceding studies, when cost-benefit analyses are conducted on international grid connections in regions that include Japan, it would be appropriate to consider items related to the countries' policy targets (effect of CO_2 reductions, renewable energy deployment) along with items related to economics and the power system. In addition, reductions to air pollutants, and not only to CO_2, should be considered as well as an item specific to Southeast Asia. The following section discusses further the process by which building interconnectors generates benefits and also identifies specific benefits.

Table 4: Examples of cost-benefit analysis for international grid connections

Assessment body (Year)	ENTSO-E CBA2.0 (2018)	Ofgem (2017)	ASEAN Centre for Energy / GEIDCO / U.N. ESCAP (2018)
Scope	European international interconnector (from 2030)	International interconnector connecting UK and other countries (from 2020's)	Southeast Asia international interconnector (2030 - 2050)
Analysis background	Expanded integration of EU energy markets and renewable energy	Promotion of UK decarbonization and electricity charges high compared to continental Europe	Realization of sustained economic growth and establishment of climate change measures in ASEAN region
Analysis objective	To provide valid information to decision-makers by clarifying the characteristics of candidate projects	To decide on approval of proposed international interconnector project	To assess the benefits of introducing renewable energy and integrating markets through international interconnection in the ASEAN region
Assesment indicators/ categories (unit)	・Socio-economic welfare*1 (Euro) ・CO_2 variation (ton) ・RES integration (MW/MWh) ・Variation in societal well-being as a result of variation in CO_2 emissions and RES integration. ・Grid losses ・Adequacy to meet demand ・System flexibility ・System stability (transient stability, voltage stability, frequency stability) ・Costs (CAPEX/OPEX)(Euro) ・Residual impact (environmental, social, other)	・Socio-economic welfare*2 (GBP) ・Improvement of reserve securement ・Improvement of supply stability ・Contribution to decarbonization ・Cost (CAPEX/OPEX)(GBP)	・R&D investment (USD) ・New employment opportunities (number of people) ・Number of people who do not have universal access to electricity (number of people) ・Average power generation cost (USD/kWh) ・Gas consumption at gas-fired power plants (m^3) ・Coal consumption at coal power plants (ton) ・Energy efficiency (%) ・CO_2 emissions reduction (ton) ・SOx emissions reduction (ton) ・NOx emissions reduction (ton) ・Total investment (USD)

Note *1: Generation cost reductions from renewable energy and CO2 costs are considered.

Note *2: Wholesale electricity market prices, decarbonization framework payments, cap and floor payments, expenses related to ancillary services, electricity sales surplus, decarbonization framework benefits, benefits from capacity mechanisms, total investment in the interconnector, total profit from the interconnector and total profit from other interconnectors are included.

Source: Renewable Energy Institute based on ENTSO-E (2018), Ofgem (2017), ACE et al. (2018)

Section 2: How interconnectors generate benefits

1) Viewing a phenomenon flow chart

With reference to the prior studies organized in Section 1, this diagram shows the phenomenon flow--which phenomena occur when an interconnector is built between Country A and Country B (Figure 11). The vertical-axis plots the general timeframe in three designations, short term, short-to-medium term and medium-to-long term. Short-term phenomena are defined as those that can be anticipated to appear simultaneously with the interconnector's construction; short-to-medium-term phenomena, within a number of years after short-term phenomena; and medium-to-long-term phenomena with development, after around 10 years, for example.

The phenomena are also categorized by their characteristics. Physical phenomena are those that can be considered to be either directly caused or caused to develop by the electric power system and interconnector; whereas economic developments, or ripple effects, are categorized as economic phenomena. When phenomena development is indicated with an arrow (→), it means the phenomenon caused another, different phenomenon. A dotted line (…) means that the phenomena are essentially the same, but also indicates the phenomenon can be viewed from a different perspective. In the phenomenon flow chart, the initial phenomenon is construction of the interconnector (Phenomenon 1). Advance surveys and studies are necessary when actually building an interconnector, and the phenomenon flow can potentially be considered from this earlier stage, but in this chart, it begins with construction.

Explanations of each phenomenon in Figure 11 are provided in Table 5. To confirm consistency with prior studies, the items in Table 5 are compared with items taken up in prior studies. To begin, prior studies discuss items evaluated as economic benefits (social welfare) and grid flexibility and supply stability.

2) Economic phenomena

First, regarding economic benefits (social welfare), Figure 11 shows Phenomenon 5 (Operation of power plants with lower marginal costs in both countries), Phenomenon 8 (Lower electricity charges), and Phenomenon 9 (Increase in [low cost] power producer sales/profits), and those are total amount of these monetary values. Specifically, like cross-regional transmission lines that join the price areas of a wholesale electricity market (wholesale electric power exchange in the narrow sense), an interconnector enables power interchange up to the capacity of the interconnector between two countries' price areas, which means lower cost power plants in that range operate even more. This is called a cross-regional merit order, and it functions across borders.

When a cross-regional merit order functions, the average generating cost of electricity for the two countries combined goes down and the profit increases for power retailers who procure electricity. Consequently, this allows electricity charges to be lowered. At the same time, in a wholesale electricity market with a functioning cross-regional merit order, power plants with lower marginal costs operate and high-cost power plants reduce their production and may possibly even completely stop operating, and the competitiveness of power sources like renewable energy that do not incur significant marginal costs to generate electricity increases.

Power plants with relatively high fuel costs, like oil-fired plants, only operate when electricity prices spike or under other specific conditions[8], so power producers are incentivized to further lower costs. When cost reduction efforts are successful, the power plant can increase its profitability, but when they are not successful, the plant would be closed.

Taking a macro view of this phenomenon, the lower profits of high cost producers caused by lower wholesale electricity prices become the source of funds returned to consumers in the form of lower electricity charges. Interconnectors promote this transfer of income, so they are constructed when a business model is established. Low cost power producers are competitive even before interconnectors are built, so further investment in them can be anticipated as a result. Introducing capacity markets in various countries is debated because there are concerns over power supply shortages due to high-cost power plants being forced to withdraw from the market.

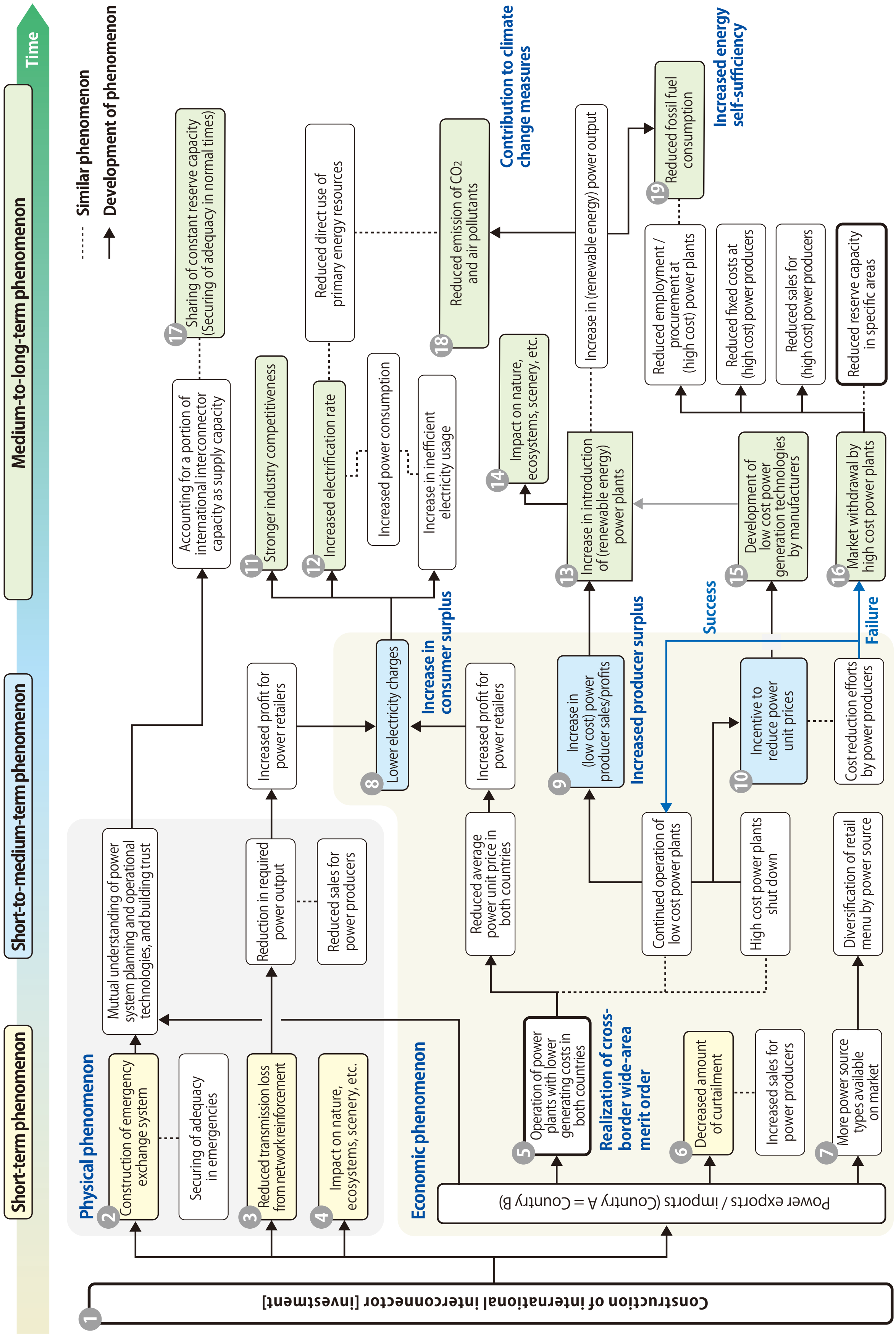
3) Physical and other phenomena

Second, the discussion of physical phenomena, specifically grid flexibility and supply stability, corresponds to Phenomenon 2 (Establishment of emergency interchange system) and Phenomenon 17 (Constant sharing of reserve capacity). If a system for emergency interchange is established and power is traded using an interconnector, it makes it possible to foster mutual understanding regarding power system planning and operating technologies and may build trust through this. As an extension of this, capacity market transactions with interconnector capacity, as is conducted in the UK, and the recording of this as supply capacity are also possible.

In preceding studies, phenomena other than items evaluated as economic benefits (social welfare) and grid flexibility and supply stability are organized and presented in Figure 11 on the medium-to-long term time axis. These are potentially brought about by the interconnector itself, but there is also the possibility of them occurring due to other outside factors. For example, expanded

8 Because of this, the need for capacity mechanisms has been pointed to in recent years, and these also have an impact on competition between power sources.

Figure 11: Phenomenon flow for interconnector between Country A and Country B



Source: Renewable Energy Institute

deployment of renewable energy is not a phenomenon brought about solely by interconnectors. However, when there is an interconnector, the quantity increases or the time shortens; it develops as a phenomenon and also has the potential to provide benefits. The benefits specifically include Phenomenon 11 (Stronger industry competitiveness), Phenomenon 12 (Increased electrification rate), Phenomenon 13 (Increase in introduction of [renewable energy] power plants), Phenomenon15 (Development of low cost power generation technologies by manufacturers), and Phenomenon 16 (Market withdrawal by high cost power plants).

Other phenomena that could be considered include, for example, the impact on tax revenue and employment from changes in power producer revenue, and the increase in investment associated with deployment of renewable energy power plants and its financial impact. However, in Figure 11, the phenomena listed are limited to the ripple effects of interconnectors based on past studies.

Table 5: Explanation of phenomena for interconnector between Country A and Country B

Pheno-menon	Phenomenon name	Content
1	Construction of international interconnector	Investment is conducted in connection with construction of an international interconnector.
2	Construction of emergency exchange system	System is constructed for securing adequacy in emergencies. For example, a system is developed in which both countries provide emergency assistance in disasters.
3	Reduced transmission loss from network reinforcement	Building an international interconnector limits loop flow and reduces transmission loss.
4	Impact (of transmission lines) on nature, ecosystems, scenery, etc.	Physical impact from construction of transmission lines and facilities occurs.
5	Operation of power plants with lower generating costs in both countries	Creating a wide-area wholesale power market creates a situation in which power plants with lower generating costs go into operation first.
6	Decreased amount of curtailment	When restrictions are placed on power plant output, power can be exported overseas via the international interconnector, so output restrictions are lessened.
7	More power source types available on market	More power sources are made available on wholesale markets in both countries.
8	Lower electricity charges	Electric power prices on wholesale power markets come down through wide-area merit order, so power retailer profits increase to create the resources for reducing electricity charges.
9	Increase in (low cost) power producer sales/profits	Sales and profits of power producers with competitiveness in wholesale power markets increase.
10	Incentive to reduce power unit prices	Power producers are incentivized to lower sales unit prices.
11	Stronger industry competitiveness	Companies' electricity-related costs are reduced, which raises the competitiveness of industry overall.
12	Increased electrification rate	There is a transition from direct use of city gas, LPG, kerosene, gasoline, diesel and other fossil fuels to services being received via electricity.
13	Increase in introduction of (renewable energy) power plants	Introduction of renewable energy power plants increase.
14	Impact (of renewable energy power plants) on nature, ecosystems, scenery, etc.	Physical impact from establishment of introduction of renewable energy power plants occurs.
15	Development of low cost power generation technologies by manufacturers	Generator manufacturers invest R&D resources into lower cost power generation technologies.
16	Market withdrawal by high cost power plants	It has been difficult to make a profit by operating high cost power plants, so these plants stop operating.
17	Sharing of constant reserve capacity	The power sources of the countries connected to the international interconnector are accounted for as the supply capacity of its own country in normal times. This makes it unnecessary to maintain surplus power facilities.
18	Reduced emission of CO_2 and air pollutants	Emission of pollutants from fossil fuels, including carbon dioxide (CO_2), nitrogen oxide (NO_X), and sulfur oxide (SO_X) are reduced.
19	Reduced fossil fuel consumption	Consumption of fossil fuels such as coal, petroleum and natural gas is reduced.

Source: Renewable Energy Institute

Section 3:
Analysis of the benefits of a Japan-South Korea interconnector

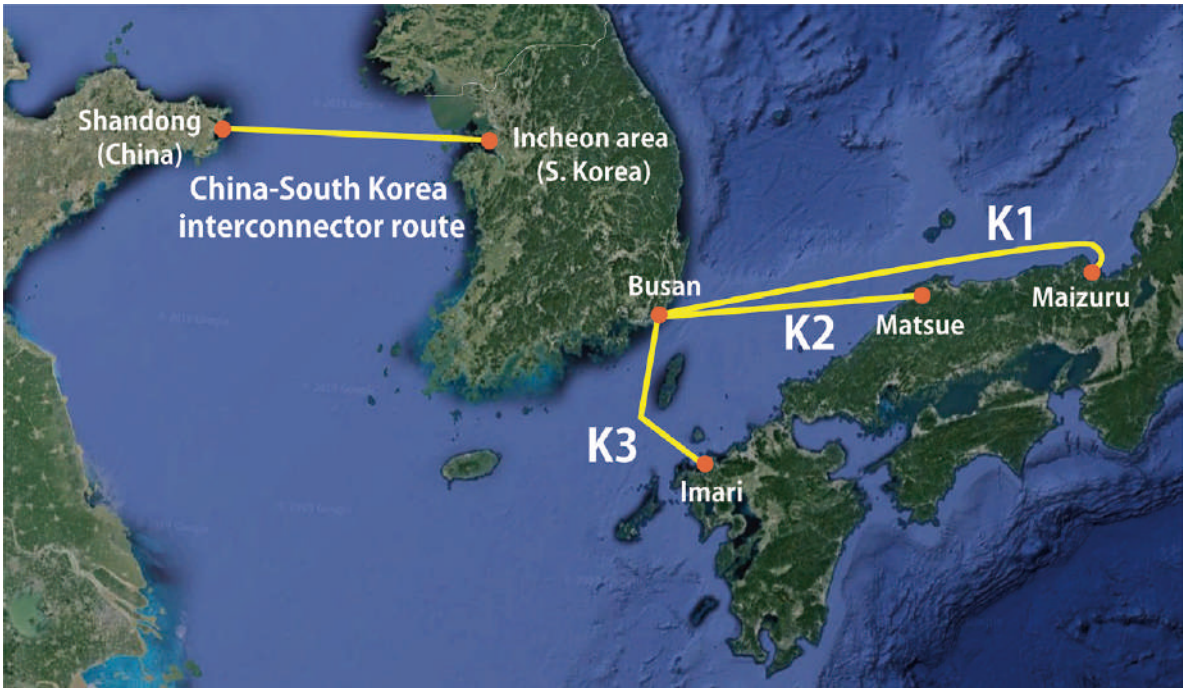
This section first looks at the phenomenon development process for an interconnector between Country A and Country B, as presented in Figure 11 and Table 5, and then considers a specific phenomenon flow using one of the Japan–Russia and Japan-South Korea interconnector routes (proposed) discussed in the ASG Second Report as an example.

1) Consideration of the phenomenon flow for a specific proposed route

In the Second Report, investment recovery was analyzed for four possible routes for Japan-Russia interconnectors and three routes for Japan-South Korea interconnectors, but the phenomenon flow here, for expedience, is considered for a single Japan-South Korea interconnector. This is because mutual transactions are possible due to South Korea having also established a wholesale electricity market. In addition, as discussed in Chapter 1, the Moon administration has embarked on large-scale deployment of renewable energy domestically, so an interconnector would contribute to this effort.

Of the three possible routes for a Japan-South Korea interconnector, we will consider here the K3 Route linking Kyushu and South Korea. Candidate routes for Japan-South Korea interconnections have not been entirely narrowed down as of July 2019, and the same considerations would be possible on other routes as well. However, given the situation with curtailment in the Kyushu area discussed in Chapter 1, focusing on the K3 Route also allows us to consider Phenomenon 6 in Figure 11 (Reduced amount of curtailment). It is assumed that the China-South Korea interconnector touched upon in Chapter 1 would have already been built and that a Japan-South Korea interconnector would be connected in with it. Figure 12 shows three possible routes for Japan-South Korea interconnectors and the China-South Korea interconnector included in these considerations.

Figure 12: Three possible routes for Japan-South Korea interconnection from the Asia International Grid Connection Study Group Second Report, and China-South Korea interconnector route



Source: Renewable Energy Institute

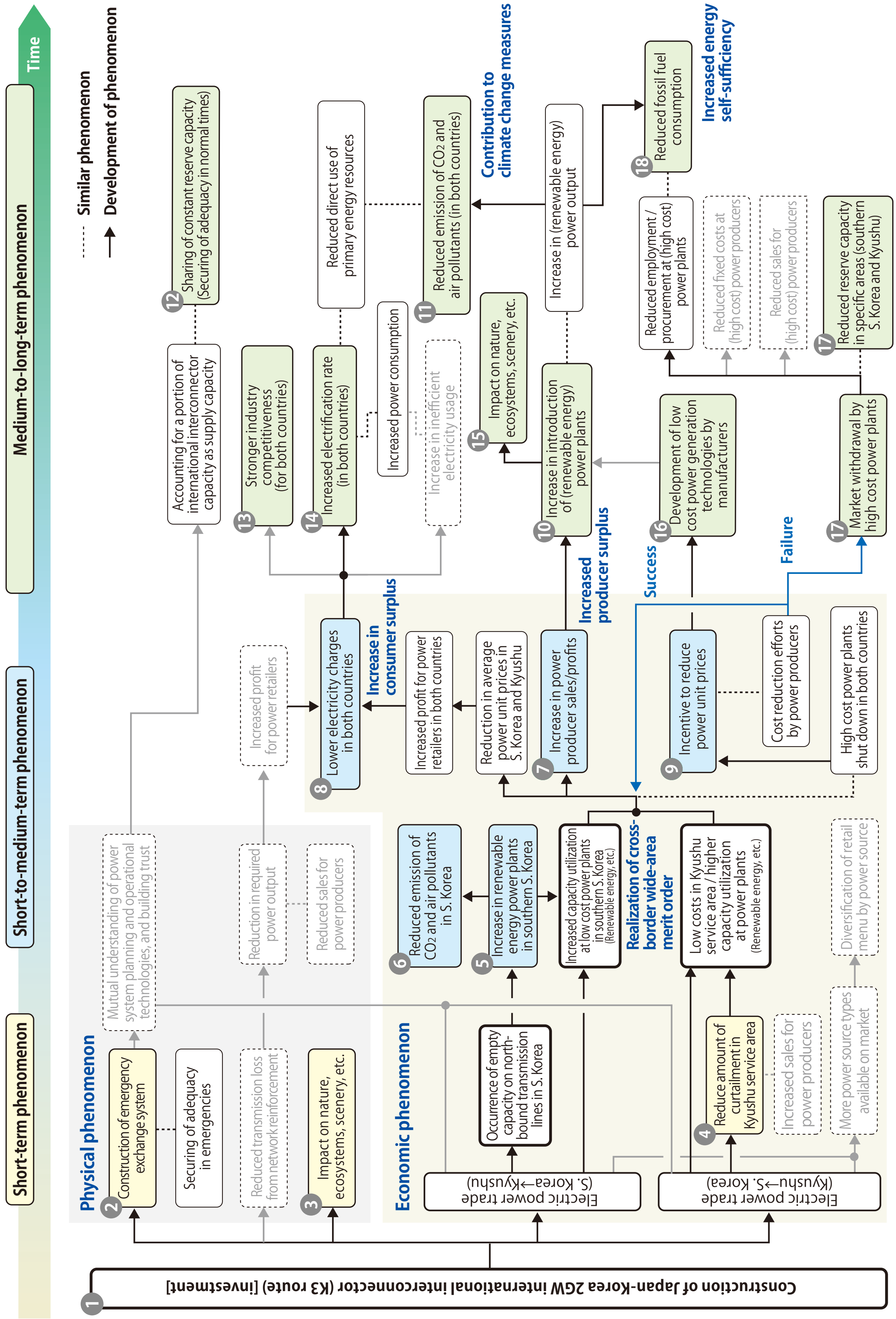
While Figure 11 shows the general phenomenon flow associated with construction of an interconnector, Figure 13 shows the phenomenon flow that results from specific consideration of the Japan-South Korea K3 interconnector route. The arrows and dotted lines on the chart are the same as Figure 11, but the light type-face here indicates it is not clear at present whether the phenomenon will actually occur. There are two main differences between the general case and the K3 Route.

The first is economic phenomena in the short-to-medium term timeframe. When electricity flows from South Korea to Kyushu, it creates available capacity on transmission lines in South Korea domestically, and this would promote further deployment of renewable energy in South Korea. Similarly, when electricity flows from Kyushu to South Korea, it can be expected to reduce the curtailment amount of solar PV and wind power in Kyushu area, which was discussed in Chapter 1. However, in the case of an interconnection between South Korea and Kyushu, it is difficult to envisage that the types of power sources handled by power retailers would change significantly, so the effect on diversification of retail power options offered by power retailers would likely be limited.

The second difference is physical phenomena in the short-to-medium term timeframe. If an emergency interchange system can be built, it would allow for mutual assistance in emergencies like natural disasters and power plant accidents, but improvements to power flows via other countries in connection with capacity shortages on transmission lines like Europe would not occur with the K3 Route. Accordingly, loss reduction from network enhancement, as is discussed with ENTSO-E, cannot be expected.

The phenomena specific to the K3 Route can be organized as follows: 1) Phenomena associated with power flows from South Korea to Japan; 2) Phenomena associated with power flows from Japan to South Korea; and 3) Phenomena related to emergency interchange. We next look at three phenomena specific to the K3 Route in detail.

Figure 13: Phenomenon flow with construction of Japan-South Korea interconnector (K3 Route)

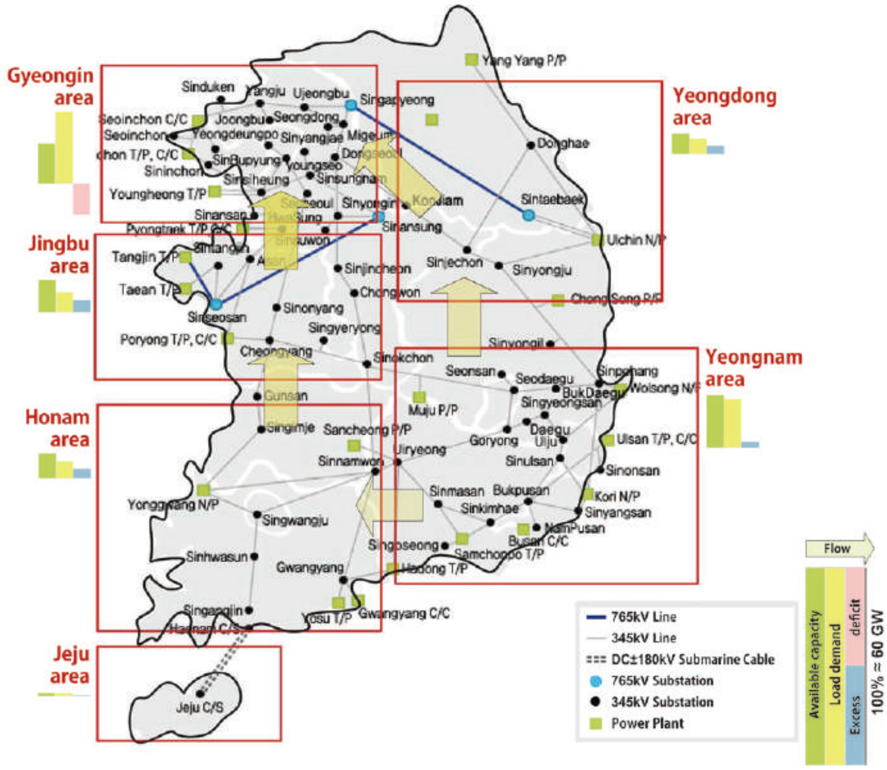


Source: Renewable Energy Institute

2) Phenomenon 1 specific to a Japan-South Korea interconnector -K3 Route: expanded deployment of renewable energy in South Korea

We first consider a phenomenon specific to when power flows from South Korea to Japan. Figure 14 illustrates power flows in South Korea. The country has numerous power sources near Seoul, capital of South Korea, a major area of electricity demand, and when there are shortages, power is supplied from other regions. The country's southeastern region, which has cities like Busan and Ulsan, has power sources that together supply over 20 GW as of 2018, which exceeds the total demand of the region. Power sources in the country's southwestern and eastern regions also provide more electricity than is consumed in the area, and, depending on the time of day, they supply power to the Seoul area via transmission lines.

Figure 14: Electric power flows in South Korea

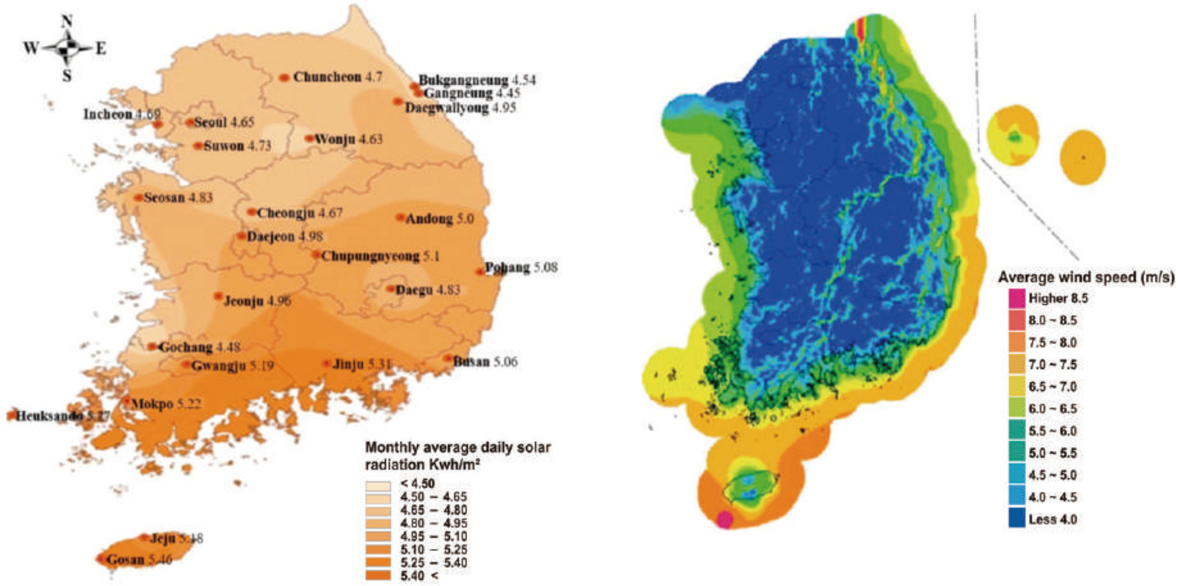


Source: Partially adapted by Renewable Energy Institute from Khan et al. (2013, p.969), Figure 15

At the same time, it can be seen in Figure 15 that geography is a factor in that South Korea's solar PV and wind power facilities are concentrated in its southern region. Transmission lines in the country running north-south are limited to a number of routes, as shown in Figure 14, so there is not much availability in transmission capacity.[9] Accordingly, when renewable energy is deployed in the amount targeted by the South Korean government, as discussed in Chapter 1, it is expected to primarily be in this southern region, so it will be necessary to create surplus capacity on domestic transmission lines. Establishing Japan-South Korea and China-South Korea interconnectors would make it possible to reduce south-to-north power flows within the country up to the amount of the total capacity of these interconnectors (up to 2 GW each for a total of 4GW). This is because it can be assumed that on the China-South Korea interconnector, generally inexpensive power will flow from China to South Korea (Seoul area), and on the Japan-South Korea interconnector, power will flow from South Korea (southern region) to Japan.

9 Based on interviews with KEPCO.

Figure 15: Map of average daily solar radiation in South Korea (left) and meteorological map of wind speeds in South Korea (right)



Source: M. H. Alsharif et al. (2018). Figures 4 and 11

3) Phenomenon 2 specific to a Japan-South Korea interconnector -K3 Route: reduced curtailment in Kyushu area

We next look at specific phenomena when electricity flows from Japan to South Korea. As discussed in Chapter 1, solar PV and wind power have been curtailed in the Kyushu Electric Power service area since 2018. One reason given is the restriction of capacity on transmission lines of the Kanmon cross-regional transmission line between Kyushu and Honshu, but construction of a Japan-South Korea interconnector on the K3 Route would make it possible to send surplus power from the Kyushu area to South Korea and reduce curtailment. This would be realized because the wholesale electricity price in Japan during renewable energy curtailment hours would be below that of the wholesale electricity price in South Korea.

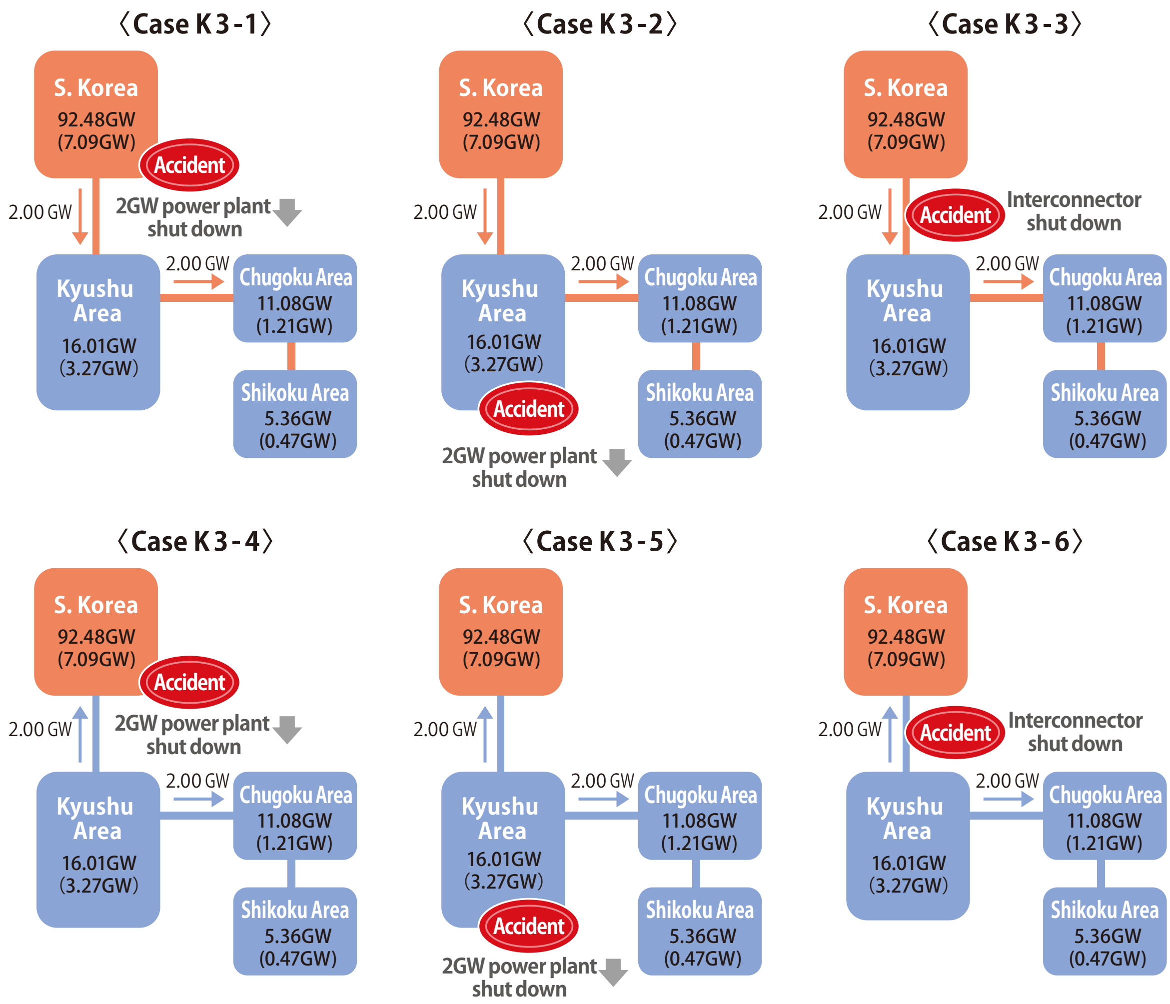
When curtailment is conducted, the JEPX price for the Kyushu area becomes 0.01 JPY/kWh in some cases. Accordingly, if Japan-South Korea interchange is conducted to the point the markets consolidate, during the hours for curtailment, the wholesale electric power exchange price in Japan would go down, so power unconsumed in Kyushu would be consumed in South Korea.

This may seem somewhat like electricity supported by Japan's FiT scheme is flowing to another country, but actually it adds value to the wholesale electricity market, so there could be secondary effects that help reduce tariffs. Under the FiT scheme as of July 2019, the difference of the purchase cost, which is based on fixed prices, minus the avoided cost is set as the tariff and collected out of electricity charges. The avoided cost is linked to the wholesale electric power exchange price, so depending on the contract price on the wholesale electric power exchange, it is possible that the FiT surcharge would be reduced. For example, supposing Japan-South Korea interchange is conducted with the Kyushu area contracting at 0.01 JPY/kWh and South Korea, at 5 JPY/kWh, and the average of both areas is 4 JPY/kWh, the avoided cost in Japan would be approximately 4 JPY/kWh, and it would be possible to reduce the FiT surcharge determined by the government by this margin. In addition, for power producers that sell electricity through the wholesale electric power exchange, contracting at appropriate prices is no doubt important from an operational standpoint.

4) Phenomenon 3 specific to a Japan-South Korea interconnector -K3 Route: establishment of an emergency interchange system

The last phenomenon specific to a Japan-South Korea interconnector that we will consider is establishment of an emergency interchange system. More specifically, in connection with reserve capacity at times of peak demand in Japan and South Korea in the summer of 2018, we will consider how an interconnector could be used in the six types of accidents shown in Figure 16.

Figure 16: Accident scenarios



Source: Renewable Energy Institute

In the case of a 2 GW flow from South Korea to Kyushu, we will consider an accident involving the stoppage of a 2 GW power plant in South Korea (Case K3-1), the same accident happening in Kyushu (Case K3-2), and an accident occurring on the interconnector (Case K3-3). In addition, in the case of 2 GW flowing from Kyushu to South Korea, we will consider an accident involving the stoppage of a 2 GW power plant in South Korea (Case K3-4), the same power plant accident happening in Kyushu (Case K3-5), and an accident occurring on the interconnector (Case K3-6). The figures for each area on the figure represent demand and the figures in parentheses are reserve margin. Japan's reserve capacity is from the report of OCCTO's Study Committee on Regulating and Marginal Supply Capability with Long-Term Supply-Demand Balance Evaluation (OCCTO, 2018c), and South Korea's reserve margin uses data published by the Korea Power Exchange (KPX) (KPX, n.d.).

The results of considerations on which phenomena would develop in each of these six cases are shown in Table 6. When electricity is imported/exported in either direction between Japan and South Korea and an accident involving the stoppage of a power plant occurs on the exporting side (Case K3-1 and Case K3-5), depending on the circumstances, emergency interchange measures would need to be taken, such as reducing flows on the interconnector. However, in both cases, if an accident occurs that stops a power plant of around 2 GW, it would be fully possible to avoid a power outage by using cross-regional transmission lines and the area's reserve margin, and flows on the international interconnector would likely only be reduced slightly for emergency interchange measures.

Table 6: Consideration of responses to accidents occurring related to the K3 Route

Accident case	K3-1	K3-2	K3-3	K3-4	K3-5	K3-6
Current	S. Korea → Kyushu area			Kyushu area → S. Korea		
Area	In S. Korea	In Kyushu	Interconnector	In S. Korea	In Kyushu	Interconnector
In S. Korea	Activate reserve capacity	No change	Curtailment	Activate reserve capacity	In some cases, activate reserve capacity	Activate reserve capacity
In Kyushu	In some cases, activate reserve capacity	Activate reserve capacity	Activate reserve capacity	No change	Activate reserve capacity	Curtailment
Japan-S. Korea interconnector flow	In some cases, reduced	No change	Zero current	No change	In some cases, reduced	Zero current
Chugoku-Kyushu interconnector flow (Kyushu→Chugoku)	In some cases, reduced	In some cases, reduced	In some cases, reduced	No change	In some cases, reduced	No change

Source: Renewable Energy Institute

However, when an accident occurs involving the stoppage of a power plant beyond current reserve capacity, or when such an accident occurs in the future after reserve capacity is reduced, the amount of emergency distribution on the interconnector could increase more than is assumed in Table 6.[10] Supposing that in Case K3-5 the accident involving the stoppage of a 4 GW power plant, it would be necessary to stop or reverse either the 2 GW flowing to South Korea or the 2 GW flowing to the Chugoku area in Japan and use this capacity to supply the Kyushu area. However, even supposing an accident that shuts down a 4 GW-class power plant, the increase in interconnector connections would mean an increased scope of response.

Upon conducting the same analysis for the K1 Route and K2 Route of the Japan-South Korea interconnector, shown in Figure 12, it was found that because reserve capacity in the Chugoku and Kansai areas is less than 2 GW, there is a strong likelihood that an accident that shuts down a power plant of around 2 GW would require emergency interchange measures from outside the area to accommodate emergency transmission. However, even in this case, if an accident on the scale of 2 GW happens, its impact on other areas would be limited, and, furthermore, even if an accident shuts down around 4 GW power plant, it was found that a more flexible measure would be possible with an interconnector.

10 In the Kyushu Electric Power service area, when trouble at a fuel supply facility forced the emergency shutdown of the Shin-Oita thermal power plant (output of approx. 2.3 GW) in the early morning hours of February 3, 2012, Kyushu Electric Power received transmission of approximately 2.1 GW from another power company. At this time, the Kanmon cross-regional transmission line was operated by switching from eastward flow of approximately 0.7 GW to westward flow of approximately 1.4 GW. Refer to Electricity Supply-Demand Verification Subcommittee (2013, p. 36).

5) Summary

The following summarizes the discussion in Chapters 2 and 3. After considering the phenomenon flow when Country A and Country B are connected by an interconnector, the following basic points were presented on interconnectors in general.

- Physical phenomena in the short-to-medium-term timeframe include establishment of an emergency interchange system, reduced transmission loss, and impact on nature, ecosystems, and scenery.
- Economic phenomena in the short-to-medium-term timeframe include realization of a cross-border, cross-regional merit order, reduced amount of curtailment, and increased power source options available to both markets. Cross-regional merit order has been evaluated in prior studies as a social welfare.

Next, we narrowed the focus to a Japan-South Korea interconnector and considered the phenomenon flow using the K3 Route as a concrete example. The following phenomena in particular were presented as potentially occurring.

- If there are electricity flows from South Korea to Japan after construction of the China-South Korea interconnector, there is the potential for a certain amount of capacity surplus to occur on south-north transmission lines in South Korea and this would contribute to increased deployment of renewable energies such as solar PV and wind power in the southern part of South Korea.
- If power flows from Japan to South Korea in hours when wholesale electricity prices in Japan are inexpensive, it would potentially reduce the amount of curtailment in the Kyushu area and, depending on the system, also reduce the FiT surcharge.
- Regarding establishment of an emergency interchange system through an interconnector, if there are power source stoppage accidents on the scale of 2 GW or an accident on an interconnector, it would be covered by reserve capacity within the area, so the amount of emergency transmission on an interconnector or cross-regional transmission line would be limited. However, if reserve capacity is diminished or a power plant larger than around 2 GW shuts down due to an accident, emergency interchange would be effective, and an interconnector would be useful as a means to more flexibly responding to the accident.

Section 4:
Stakeholder analysis for a Japan-South Korea interconnector

1) Organizing phenomena with benefit incidence table

This section discusses how each phenomenon in the phenomenon flow for the K3 Route considered in Section 3 impacts stakeholders based on the approach of a benefit incidence table. Benefit incidence tables organize the benefits to stakeholders of public works investment on each benefit (Morisugi, et al., 1988). The tables organize the contribution to stakeholder phenomena, which are based on differing principles of behavior, so they have the advantage of clarifying the benefits and losses to each category of stakeholder (Itaba, 2009; Meguro, Kasashima, 1999).

Stakeholder benefits for phenomena numbered 1 to 18 in Figure 13 are organized and the results are presented in Table 7. However, typical analysis with benefit incidence tables presents the findings of quantitative evaluations with respect to each phenomenon, but our considerations stop at qualitative discussions and are organized from the standpoint of whether each phenomenon functions as a positive or a negative for such stakeholders.

Table 7: Findings of benefit incidence evaluation (qualitative) for the K3 Route

	K3 Route Assessment of benefits and losses when each stakeholder is directly connected to the respective phenomena	International transmission providers	Grid operators in areas connected by international interconnector		Consumers		(High cost) power producers	(Low cost) power producers	(Low cost) generator manufacturers	Residents near facilities	Policy makers (Policy goals)	
			Kyushu	S. Korea	Kyushu	S. Korea					Japan	S. Korea
	① Construction of international interconnector (investment)	−										
Short-term phenomenon	② Construction of emergency exchange system		+	+								
	③ Impact (of transmission lines) on nature, ecosystems, scenery, etc.									−		
	④ Reduce amount of curtailment in Kyushu service area		+		+			+				
Short-to-medium-term phenomenon	⑤ Increase in renewable energy power plants in southern S. Korea			+ / −		+	+ / −	+	+			+
	⑥ Reduced emission of CO_2 and air pollutants in S. Korea					+				+		+
	⑦ Increase in power producer sales/profits **(Increased producer surplus)**						−	+ / −				
	⑧ Lower electricity charges **(Increase in consumer surplus)**				+	+					+	+
	⑨ Incentive to reduce power unit prices						+ / −	+	+			
Medium-to-long-term phenomenon	⑩ Increase in introduction of (renewable energy) power plants		+ / −	+ / −	+	+	+ / −	+	+		+	+
	⑪ Reduced emission of CO_2 and air pollutants **(Contribution to climate change measures)**				+	+				+	+	+
	⑫ Sharing of reserve capacity	+	+	+			−	+ / −				
	⑬ Stronger industry competitiveness										+	+
	⑭ Increased electrification rate				+ / −	+ / −	+	+	+			
	⑮ Impact (of renewable energy power plants) on nature, ecosystems, scenery, etc.									−		
	⑯ Development of low cost power generation technologies by manufacturers						+	+	+ / −			
	⑰ Market withdrawal by high cost power plants (Reduced reserve capacity in specific areas)		+ / −	+ / −			−	+				
	⑱ Reduced fossil fuel consumption **(Increased energy self-sufficiency)**				+	+					+	+

Source: Renewable Energy Institute

Short-term phenomena

Phenomenon 1 (Construction of international interconnector) is an investment activity by the interconnector provider, so it is a negative in that costs are incurred. Phenomenon 2 (Establishment of emergency interchange system) functions as a positive for grid operators in both countries. Phenomenon 3 (Impact of transmission lines on nature, ecosystems, scenery) is a negative for people living near the facilities regardless of the country because transmission lines mainly affect the areas where they are actually constructed. A phenomenon specific to the K3 Route, reduced amount of curtailment in Kyushu service area (Phenomenon 4), is a positive for grid operators given their original duty and purpose, and has been evaluated as a positive for consumers, who will be able to use more renewable energy, and for low-cost power producers who operate power plants.

Short-to-medium-term phenomena

Phenomenon 5 (Increase in renewable energy power plants in southern South Korea) is evaluated as a positive in some cases and a negative in other cases because operations by grid operators in South Korea will change from how they are currently. Additionally, for consumers in South Korea, it is a positive because they will be able to use more renewable energy, and for high-cost power producers, it has the potential to negatively impact the operations of existing power plants, but depending on market price trends, it could work as a positive for some producers, so there are both positive and negative aspects for them. However, for low-cost power producers and plant developers, increased deployment itself will work as a positive. In addition, for policymakers or policy goals, increased deployment of renewable power plants itself is a positive phenomenon. Phenomenon 6 (Reduced emission of CO2 and air pollutants in South Korea) was assessed as a positive for people living near power plants, consumers and policymakers or policy goals.

Phenomenon 7 (Increase in power producer sales/profits) would be a positive for low-cost power producers who would reap this benefit. However, the average price on the wholesale electricity market would be reduced overall, so even among low cost power producers some may be negatively impacted; the phenomenon was also assessed as a negative for high cost power producers. Phenomenon 8 (Lower electricity charges) would be a positive for consumers and policy officials responsible for the power system. Phenomenon 9 (Incentive to reduce power unit prices) is a positive because low costs are why low-cost power producers exist, but for high-cost power producers, new efforts will be required, so both positive and negative impacts are possible, and both have been indicated. For low-cost power plant manufacturers, the incentive to reduce generating costs serves as an opportunity to expand business, so it was evaluated as a positive.

Medium-to-long-term phenomena

Medium-to-long-term phenomena are potentially impacted by other outside factors, so whether it is valid to make evaluations for current stakeholders is a matter for debate, but like with short-to-medium-term phenomena, qualitative evaluations have been made. Phenomenon 10 (Increase in introduction of renewable energy power plants) and 11 (Reduced emission of CO2 and air pollutants) are the same as Phenomenon 5 and Phenomenon 6, and the evaluation included Kyushu as a region where the plants would be deployed. Phenomenon 12 (Constant sharing of reserve capacity) was assessed as a positive for international transmission operators because it will create new business opportunities and also as a positive for grid operators because it will enhance the reliability of the power supply. However, because the overall cost to society to secure reserve capacity will go down, overall power producer sales will decrease, while at the same time for some low-cost power producers, it is possible their sales will increase because they will be able to provide more reserve capacity. Accordingly, the phenomenon was assessed as a negative for high-cost power producers and both a positive and a negative for low-cost power producers.

Among the stakeholders shown in Table 7, Phenomenon 13 (Stronger industry competitiveness) would serve as a positive for policymakers or policy goals. It would also likely have a major impact on workers, regular companies and other stakeholders not listed in Table 7. Furthermore, for consumers, an increased electrification rate (Phenomenon 14) would be a positive (for example, a decrease in overall energy costs) or a negative (increased expenditures for required new equipment) depending on their circumstances, so it was assessed as having both positive and negative aspects. However, for power producers and generator manufacturers, it was assessed as a positive because electricity consumption itself would increase.

Phenomenon 16 (Development of low-cost power generation technologies by manufacturers) was assessed as being both a positive and a negative for power producers; a positive because their competitiveness would be bolstered, and a negative for manufacturers because increased business opportunities would increase the burden of development costs. Phenomenon 17 (Market withdrawal by high-cost power plants (reduced reserve capacity in specific areas)) for grid operators would be a positive because supply-and-demand balancing could be performed with more inexpensive power sources and a negative because concerns could arise about a decline in supply reliability. Also, it would be a positive for low cost power producers because there would be fewer competitors and a negative for high cost producers forced to withdraw from the market.

Finally, reduced fossil fuel consumption (Phenomenon 18) was evaluated as a positive for consumers because reducing fossil fuels means less risk of supply instability and consumers would benefit from stable energy supply over the medium-to-long term, and as a positive for policymakers because a higher energy self-sufficiency is a desirable end.

2) Summary

Based on this analysis, stakeholders that would be negatively impacted over the short-to-medium term by a Japan-South Korea interconnector include power producers and residents living in areas where facilities would be built. Among these, power producers operating with high cost power plants would need to rethink their business. And even low-cost producers would be subject to more pressure to further reduce costs. Accordingly, power producers will have to transition to generating technologies that further lower costs overall, and in some cases invest in and enter new business areas like the interconnector business.

For people living where transmission lines and renewable power plants would be built, the facilities may have some impact on scenery and ecosystems, but existing thermal power plants would shut down, which would bring the benefit of reduced air pollutants like NOx, SOx, and particulate matter (PM). It would also be important to utilize lower impact technologies like underground transmission lines. Based on these factors, when facilities are to be established, it will be important to make considerations based on a process that includes environmental assessments.

Regarding stakeholders other than power producers and people living near the facilities, international interconnectors generate many phenomena that are generally positive. Accordingly, in promoting interconnectors, it is important to have a sufficient understanding of stakeholders negatively affected and to take proactive initiatives with respect to stakeholders on whom the impact is positive.

Column:
International gird connections and the environmental value of electricity

One of the benefits of international grid connections is their contribution to renewable energy growth because of how they help mitigate the effects of output fluctuations. So how is the environmental value of electricity imported and exported assessed, and more specifically, how are carbon dioxide emissions counted? When electricity is imported by Country A from Country B, which country counts the carbon dioxide emissions from its generation? Also, when a company in Country A purchases and consumes electricity imported from Country B, is it counted among that company's emissions? The matter of how carbon dioxide emissions from electricity subject to international transmission are handled is stipulated as follows in international guidelines on national greenhouse gas inventories and guidelines on calculating corporate emissions.

1) National emission calculations

Countries that are party to the United Nations Framework Convention on Climate Change (UNFCCC) are obligated to calculate and publish their greenhouse gas emissions every year in accordance with the inventory guidelines of the Intergovernmental Panel on Climate Change (IPCC). The guidelines stipulate that countries are to calculate the emissions they directly generate within their borders. With regard to emissions from the electricity generation sector as well, only greenhouse gases generated from burning fuel in that country are counted. Accordingly, emissions from electricity generated at a thermal power plant in Country A is counted in full as the emissions of Country A even if it is transmitted to Country B via international grid connections and consumed in Country B.

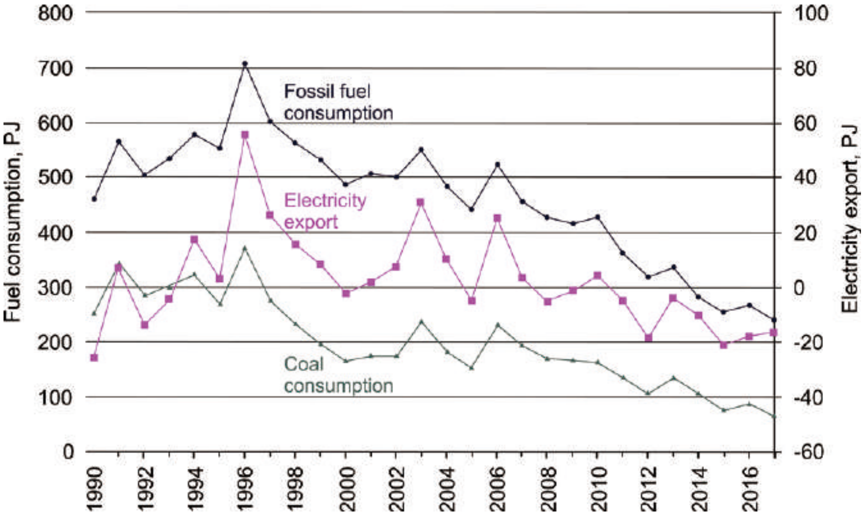
In Europe, where international transmission is already actively taking place, emissions are in fact calculated and disclosed for each country in accordance with this method of tabulation. As an example, we will look at the case of Sweden and Denmark.

Sweden supplies close to 60% of its electricity with renewable energy, and it is primarily hydropower. Hydropower electricity generated fluctuates depending on weather conditions each year, so when output is low, it is supplemented with other domestic power sources or with electricity imported from other countries. As to how emissions are calculated in this case, the National Inventory Report Sweden 2019 (Swedish EPA, 2019) submitted to the UNFCCC shows that among years in which hydropower electricity generated was low, emissions were low in 2003 when the shortage was supplemented primarily with imported electricity and high in 1996 when it was supplemented with domestic coal-fired power (Swedish EPA 2019, p. 82).

At the same time, Sweden's electricity trade partner, Denmark, in its emissions report, Denmark's National Inventory Report 2019 (DCE, 2019), also states that carbon dioxide emissions increase in years with large electricity exports and decrease in years with large electricity imports. "Thus, the high emissions in 1991, 1996, 2003 and 2006 reflect a large electricity export and the low emission in 1990, 2005, 2008, 2011 and 2012 is due to import of electricity." (DCE 2019, p. 15).

The report also states that Denmark's electricity generated is highly dependent on the electricity trade with Sweden and Norway, and the above "large electricity export in 2003" can be understood as "the counterpart to Sweden's decline mentioned above in hydropower in 2003 being covered primarily by electricity imports", as stated in its report. According to the report, Denmark has many coal-fired power plants that are not normally used and operate only when electricity demand is high; in years with large electricity exports, use of coal and other fossil fuels increases, as can be seen in the graph (Figure 17).

Figure 17: Fluctuations in electricity export compared to fuel consumption in Denmark



Source: Partially adapted by Renewable Energy Institute from DCE (2019), Figure 3.2.4

Taking the Sweden and Denmark emission reports together, it can be seen that carbon dioxide from electricity from coal-fired power exported from Denmark to Sweden is counted as Denmark's emissions and not included in Sweden's emissions, which is in accordance with the IPCC's inventory guidelines.

2) Corporate emission calculations

When calculating national greenhouse gas emissions based on UNFCCC guidelines, as shown above, the import country's emissions do not increase even when electricity from fossil fuel power sources is imported. Different rules apply, however, when the emissions of individual corporations are calculated.

Corporate greenhouse gas emissions are calculated using standards and guidelines from the Greenhouse Gas Protocol[11] established in 1998, which is the de facto international standard. The protocol is recommended by initiatives like the CDP Climate Change Questionnaire, RE100 and Science Based Targets (SBT). The protocol classifies greenhouse gases subject to calculation into three categories, and "emissions from the generation of acquired and consumed electricity, steam, heat, or cooling (collectively referred to as "electricity")" are defined as "scope 2." The method used to calculate scope 2 emissions is provided in GHG Protocol Scope 2 Guidance (Greenhouse Gas Protocol 2015, p. 34) published in 2015.

The protocol provides two basic methods for calculating emissions from the generation of acquired and consumed electricity, market-based and location-based. The market-based method uses in calculations emission factors for "emissions from electricity that companies

11 Partnership convened by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). It seeks to standardize GHG inventories for private-sector companies, public institutions, product value chains and GHG reduction projects.

have purposefully chosen," and the location-based method uses "the average emissions intensity of grids on which energy consumption occurs".

In regions where companies are completely unable to select the type of electricity they procure and also unable to use certificates like green power certificates, calculating emissions only with the location-based method is allowed, but in all other cases, companies are required to calculate with the market-based method as well and report their emissions based on this method. Presently, in nearly every country, it is possible to acquire a Guarantee of Origin or some other certificate related to the environmental performance of the electricity being used, so effectively companies are required to report emissions using the market-based method.

There are five categories of methods for calculating emission factors that are used with the market-based method, and they include certificates that certify energy attributes (renewable energy certificates issued in the U.S., Canada, Australia, the EU's Guarantee of Origin, and the like) and contracts for electricity (PPA), and the methods themselves are ranked.

Calculating electricity emissions in accordance with these guidelines is naturally applied to international transmissions as well, so when Company X in Country A contracts with an electricity supplier in Country B and purchases renewable electricity from Country B, it reduces emissions from Company X's consumption of that electricity. Conversely, if electricity with a high emissions factor is purchased, emissions increase. With this the case, the supply of renewable electricity through international grid connections creates business opportunities to a certain extent from the standpoint of the transfer of environmental value.

3) Application in Japan

If international transmission between Japan, South Korea, China and other countries is realized, how would the above rules be applied? First, each country's emissions would be calculated based on the UNFCCC guidelines, so if Japan's thermal electricity generated were reduced by importing electricity from overseas, Japan's GHG emissions from electricity generation would be reduced. Conversely, if domestic thermal electricity generated were to increase due to electricity exports, emissions would increase.

When calculating corporate emissions, there are two cases to be considered. In Japan in recent years as well, more and more companies are voluntarily calculating and publishing their emissions through CDP, SBT and other initiatives as a part of their climate change measures. In such cases, calculations are made on the basis of the above international guidelines. When renewable energy is purchased by some method from overseas, it reduces emissions from electricity.

Apart from this, companies in Japan are required to calculate emissions for the Mandatory Greenhouse Gas Accounting and Reporting System, which is mandated under the Act on Promotion of Global Warming Countermeasures. The system requires that companies include in their calculations carbon dioxide emissions from use of electricity supplied from other parties. The system at present does not make stipulations about the handling of electricity imported through international transmission. To realize international grid connections, it will be necessary going forward to clarify rules within the system for calculating emissions factors for imported electricity as well.

Chapter 4: International grid connections and energy security

This chapter considers energy security issues surrounding international grid connections. Generally, in Europe and elsewhere, international grid connections are thought to contribute to energy security. This is because when electricity is exchanged across international borders, it positively affects supply stability from the standpoint of reserve capacity and also increases energy self-sufficiency because it helps mitigate the effects of output fluctuations from renewable power. By contrast, in Japan, due to a lack of experience with international transmission, security concern is sometimes voiced that exports from neighboring countries could be arbitrarily suspended. In response to this concern, we will first clarify the traditional concept of energy security, which is based on fossil fuels, and then, with respect to electricity security in relation to international grid connections, we will explain that the approach to security is somewhat different and electricity exports being suspended for political reasons would not present much of a problem at all for Japan. Moreover, when the era of large-scale deployment of renewable energy arrives, we point out that the concept of energy security will change completely.

Section 1: The concept of energy security in the fossil fuel era

1) Energy security and three risks

What originally is the source of concern about energy security? In the Ministry of Economy, Trade and Industry's Energy White Paper 2010, energy security is highlighted. According to this definition, "energy security refers to being able to secure energy in the 'quantity' necessary for people's lives, economic and social activities, and national defense at affordable 'prices'." National security refers generally to protecting the nation's territory and independence through diplomacy and military force. By contrast, energy, along with food and other goods, is indispensable to the continued functioning of a nation's economy and society, so the government has a certain role to play in securing it.

This concept can be further considered by dividing it into three risks. The first is geopolitical risk. As typified by fossil fuels, energy is often traded across borders. Political stability and diplomatic relations in regions like the Middle East and Africa have a major impact on energy trade and transport, a fact that can be clearly seen from the factors underlying past wars. For Japan, which is dependent on substantial energy imports, this is a particularly important risk, which is also related to the abovementioned suspension of exports due to political reasons. Diplomacy is a public good that the government supplies directly, so the government's role in mitigating geopolitical risk is not small.

The second category of risk is geological risk. Oil resources in particular are heavily concentrated in the Middle East and other specific regions and they will eventually be depleted. Even if they are not physically absent, when there are shortages, the price can spike. As a measure to address this, oil field development is taking place domestically and overseas, but commercial and geopolitical risks are both high and a high level of involvement is required on the part of the government. A more fundamental measure would be to immediately increase dependence on renewable energy, which is a non-depletable domestically produced resource.

The third risk is the supply system from a facilities and technology standpoint. Primary energy supplied from domestic and foreign sources is converted to secondary energy—city gas, gasoline and electricity—and supplied to consumers through gas and electricity networks. When this infrastructure is underdeveloped, or the technical level of operations is low, or the market system is inadequate, it can, for instance, cause power outages from insufficient power plants, supply network fragmentation in natural disasters, and price surges caused by speculative trading. It is well known that power outages frequently occur in developing countries, and they can be potentially addressed with facilities investment and technician training, which should be primarily borne by business actors.

2) Fossil fuel security and the oil crisis

The above three risks generally apply to energy overall, but energy security has basically meant the various problems attending fossil fuels. Among fossil fuels, oil has been emphasized the most, and among the three risks above, geopolitical risk has drawn the most focus. This is because as a fuel used for transportation, including in the military sector, oil is a strategic energy that is difficult to substitute, and it is concentrated in the Middle East, Africa, Russia, and South America. As a consequence of this, two oil crises occurred in the 1970s.

In the first oil crisis, the Arab-led Organization of the Petroleum Exporting Countries (OPEC) significantly raised oil prices in protest against the fourth Arab-Israeli war and placed restrictions on exports to the United States and other countries supporting Israel. The result was economic turmoil in developed countries, including Japan, in the form of rapid inflation and supply shortages. In response, developed countries jointly established the International Energy Agency (IEA) and attempted to cope by stockpiling reserves.

Oil field development in non-OPEC countries made progress thereafter, which loosened the oil supply-demand balance and led to an increase in transactions through international markets. This in turn made it more difficult for a portion of export countries to join together and form a political cartel, and the act of suspending oil exports to developed countries ceased. At the same time, since the 1990s, the economies of emerging countries, China and India specifically, have developed rapidly, and now consumer countries, including developed countries, compete among themselves to secure resources.

3) Suspension of exports for political reasons

In recent years in particular, Russia's suspension of natural gas exports has been regarded as problematic. It may be that Japanese concerns about international grid connections have been significantly influenced by Russia's actions.

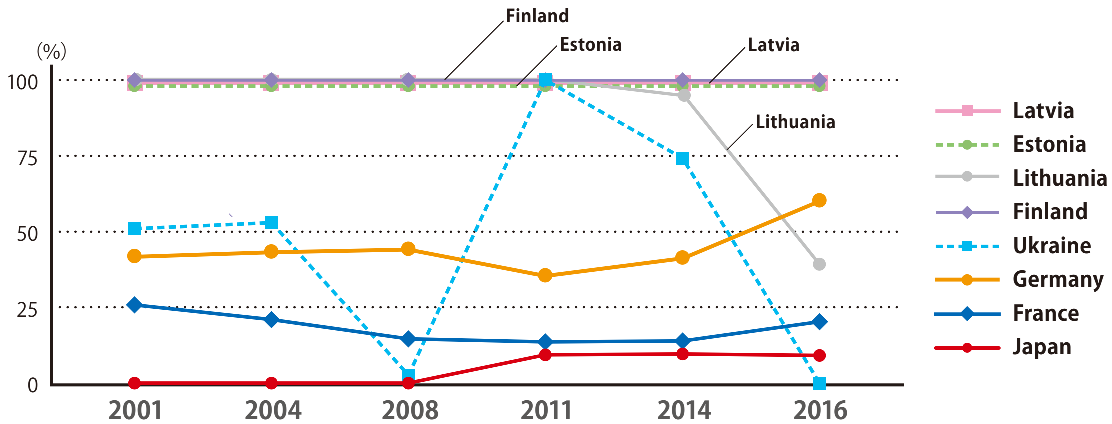
For example, Gazprom, Russia's state-owned gas supplier, has since the 2000s stopped the supply of natural gas to Ukraine a number of times. In response, Ukraine has strongly criticized Russia for inappropriately suspending exports for political reasons in connection with its new pro-Europe administration. In response, Russia argues that the act is retaliation for unpaid gas charges and tapping pipelines without permission and that rate hikes apply to other countries as well. Actually, it has been pointed out that such an act, or threat, between Russia and major European countries, where economic problems related to gas charges are not a factor, did not occur even during the Cold War.

In reality, it is difficult to delineate between political reasons and economic reasons, and economic factors are sometimes given to make threats for political purposes. In cases like this, exporting countries do not blindly cut off exports; they do so after considering and judging the various advantages and drawbacks.

One advantage is that as a result of the act its political ends are realized. In the case of Ukraine, the act could deal a blow to the pro-Europe administration and as a result the regime might yield to Russia, or in some cases be overthrown. However, there are more than a few drawbacks as well: export revenue declines, international criticism mounts, distrust among other import countries increases. When the export country takes the action despite the drawbacks, it is likely an extremely asymmetrical situation in which the export country is in an extremely dominant position economically and militarily and the import country is extremely dependent on the export country without other enough procurement means.

It is true that in the case of the former Soviet Union, an integrated energy system was built centering on Russia and the post-Soviet states are today still highly dependent on Russia (Figure 18).[12] To put it another way, building energy and economic systems not excessively relying on any specific country serves to diversify risk. This would mean, for example, having multiple pipelines and importing from multiple countries,[13] raising the import rate from friendly countries and conducting transactions through international markets, and having storage facilities domestically.[14]

Figure 18: Dependence on natural gas imports from Russia



Note: "Dependence on Russia" is imports from Russia divided by total imports. Latvia, Estonia and Finland continue 100% dependence.
Source: Renewable Energy Institute based on IEA (2006, 2013, 2018, 2019)

Section 2: Electricity security and international grid connections

1) Electricity characteristics and security

When energy security is considered in connection with electricity traded through international grid connections, attention must be given to the characteristics of electricity as a form of energy. Electricity is a secondary energy, so there are significant differences in how energy security is considered compared to oil and natural gas discussed above.

Firstly, regarding the geopolitical risk, electricity can be exported and imported, but compared to fossil fuels, a large proportion of its supply in most cases comes from domestic sources. That is to say, most countries normally possess a certain amount of generating facilities within their own borders, and there are very few countries that perpetually import more than half their electric power from sources overseas (Table 8). If a country's import rate is low, the effect of exports being suspended will be limited.

12 As shown in Figure 18, Finland also imports 100% of its natural gas from Russia, but there have thus far been no problems with exports to it being suspended.
13 Since 2009, Japan has imported LNG from Russia, and this is contributing to diversification of its import sources.
14 From this perspective, Latvia effectively utilizes its own domestic natural gas storage facilities, and Lithuania has built an LNG terminal and begun importing LNG from Norway and other sources.

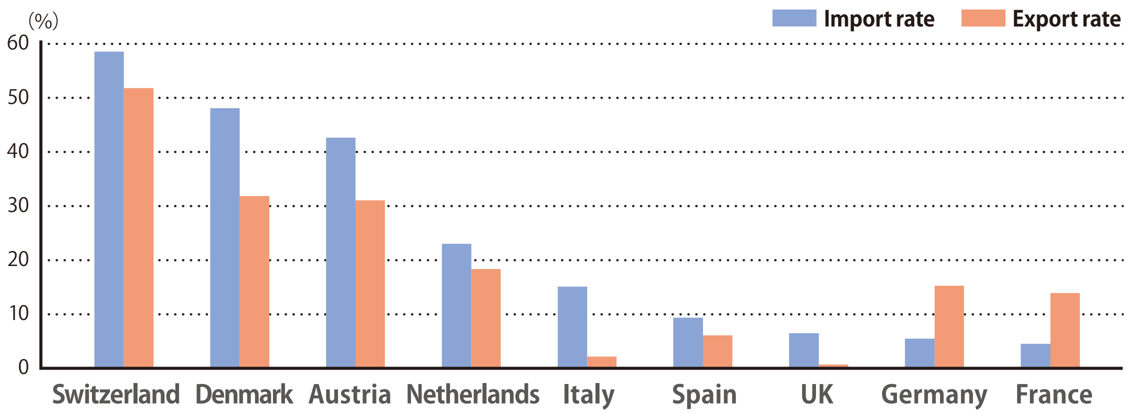
Table 8: Import rates by energy type and region (2016)

	Coal (World)	Oil (World)	Natural Gas (World)	Electricity (World)	Electricity (OECD)	Electricity (OECD Europe)
Imports	795 Mtoe	2,379 Mtoe	915 Mtoe	722 TWh	476 TWh	395 TWh
Area supply	3,657 Mtoe	4,473 Mtoe	3,032 Mtoe	25,082 TWh	11,007 TWh	3,630 TWh
Imports ratio	21.7%	53.2%	30.2%	2.9%	4.3%	10.9%

Note: Import rate = Imported amount / total area supply
Source: Renewable Energy Institute based on IEA (2019a)

In addition, though Europe is the region with the highest import rates of electricity in the world (Table 8), Switzerland and Denmark, whose rates are particularly high, also export equivalent amounts (Figure 19). The countries are nodes in the electric power trade, and it is precisely because they already have sufficient supply capacity domestically that they are able to import and export easily in both directions, which means the risk of becoming asymmetrically dependent on overseas sources is low. Also, in Europe, market integration measures have been robustly promoted, which is one factor that has led to this result, and when the international market develops to this extent, there is almost no risk of exports being suspended for political reasons.

Figure 19: Electricity import and export rates of European countries (2016)



Note: Import rate = Electricity imports / electricity consumed Export rate = Electricity exports / electricity consumed
Source: Renewable Energy Institute based on IEA (2019a)

In contrast with these examples, Lithuania's import rate is 114% (export rate of 29%), and Latvia's import rate is 75% (export rate of 59%), which are extremely high. Under the totalitarianism of the former Soviet Union, the integrated power system was partially formed by force. For this reason, the now independent Baltic states in recent years have been withdrawing from Russia's synchronous grid and integrating with European power systems and markets (European Commission, 2018). This could be considered a measure to mitigate geopolitical risk, but it is also a very unique case.

Secondly, regarding the geological risk, even though electricity itself is domestically produced, the fossil fuels used to generate the electricity are very often imported. Since the Fukushima Daiichi nuclear accident in 2011, it is well known that Japan's power sources have depended on imports at a rate of 80% or higher. However, if renewable energy's share increases going forward, geological risk will decrease. Compared to other consumption sectors such as heat and transportation, deployment of renewable energy is making headway in the electric power sector, and if it continues to progress, the security of electricity will also increase. This will be taken up again in the following section.

Thirdly, regarding the supply system risk, electricity is characterized by the fact that the system operates on a transmission grid. Compared to importing oil by tanker, the supply system is capital intensive and strongly restricted geographically in terms of where facilities are installed; the situation is similar to a pipeline. It is also difficult to store energy (electricity), so when the supply-demand balance breaks down, blackouts can potentially occur, which makes it different from other forms of energy. Furthermore, the output variability of solar PV and wind power as forms of renewable energy can potentially inhibit supply stability. One rational measure to address this is cross-regional transmission operations, which, as has been pointed out, is precisely the reason why international grid connections are currently being expanded.

2) Contribution of international grid connections to energy security

Based on the above considerations, electricity traded through international grid connections generally contributes substantially to energy security.

First, building or enhancing international grid connections on the assumption of a certain level of domestic supply capacity enables diverse import/export routes to play a supplementary role in reserve supply capacity, increases supply stability and makes it possible to reduce supply costs. Compared to oil and other power sources, electricity readily produces benefits from mutual, international reliance.

Secondly, when international grid connections contribute to deployment of renewable energy as a measure to mitigate output fluctuations, it makes it possible to raise energy self-sufficiency. When renewable power comes to account for over 50% of the power supply, as was analyzed in Chapter 3, it means a major reduction in imports of coal and natural gas used in thermal power generation, and, as will be discussed in the next section, it potentially means a fundamental change in the energy security environment.

In addition, with regard to the arbitrary suspension of electricity exports, the risk is extremely low compared to fossil fuels. Almost all countries have a certain amount of electricity generation facilities, so the effect of stopping exports is limited. Electricity by its nature is difficult to store and it is also difficult to resell.

Import countries can further lower this risk by building not just one but multiple interconnectors that connect not one but several countries. This would also be an effective way to keep imports below a certain percentage. Using Japan as the example, if the 2 GW interconnector proposed in the Second Report is built, it would account for just 1.1% of the country's supply capacity in times of peak demand in fiscal 2018, and just 3.3% of capacity in the TEPCO service area, and moreover, only 10.4% of capacity in the Kyushu Electric Power service areas.[15] Of course, transmission volume is bound to increase in the future, and when this happens, it will be effective to integrate market systems under a multi-country framework. Also, when construction and investment for an interconnector is not borne by the import country alone but by both countries and operations are conducted jointly, the possibility of exports being stopped unilaterally is reduced.

15 Regarding fiscal 2018 supply capacity during peak demand, refer to OCCTO (2018b, p. 5).

3) Electricity export suspension and emergency interchange examples

It is extremely rare for exports of electricity to be suspended for political reasons, but looking at the actual rare cases, it shows that it has occurred under limited, unique circumstances.

For example, Uganda suspended electricity exports to Kenya in 1976 (Gore, C.D., 2017). This was initiated by Uganda's military government against the backdrop of a territorial dispute in western Kenya. Kenya's electricity supply at the time was largely dependent on imports from Uganda, and the lost electricity represented around 15-20% of Kenya's supply capacity. It was an event in the midst of mounting diplomatic tensions, and exports were again suspended in 1987. Diplomatic relations between the two countries have been good in recent years, and the East Africa Power Pool's[16] international connection project is being promoted with neighboring countries. Kenya has also promoted geothermal development and now also exports power to Uganda (Richter, A., 2015).

There is another example from within a single country. In 2017, Ukrenergo, a transmission provider in Ukraine stopped supplying electricity to the Donbass region in the eastern part of the country (Ukrenergo, 2017). On the surface, the reason given was unpaid electricity charges, but the act was retaliation against pro-Russia separatists in eastern Ukraine mobilized by the Crimean issue, and it can be considered as control toward Russia, with which the country is actually in the state of war.

By contrast, there are also cases in which stable supplies are maintained thanks to emergency electricity imports from other countries. France in February 2012 was beset by an extremely cold winter (Météo France, 2012), and heating demand rose to record levels, forcing the country to import 8% of its electricity demand at the time from foreign sources. It imported 8.3 GW from all the countries around it, including Germany, Belgium, the UK, and Spain, and weathered the supply-and-demand crunch (RTE, n.d.).

In another example from France, the country was forced to shut down its nuclear power plants from 2016 to 2017 due to safety issues in their generating facilities. France depended on nuclear power for approximately 70% of its total electricity generated, so a major supply shortage resulted, and in January 2017 alone it imported approximately 1 TWh of electricity (RTE, 2017). This not only preserved supply stability in France, it helped rein in spot prices on a surging market.

What we can learn from these examples is that electricity exports are arbitrarily suspended only in very rare circumstances, such as in regions destabilized by military conflict or between countries with authoritarian governments. In general, there is virtually no benefit to the export country from suspending exports to countries like Japan with large economies and stable politics, and it is nearly inconceivable that it would occur. Rather, for Japan and for the partner country, being connected by an interconnector is much more likely to result in the possibility of emergency interchange for sudden supply capacity shortages, like what happened in Hokkaido in fall 2018.

4) Addressing export suspension through international agreements

Countries actually engaged in electricity trade through interconnectors are generally subject to certain legal restrictions established through international agreements. They include agreements on free trade in general and specifically on energy and serve to deter acts of export suspension (Table 9).

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16 International electricity market in East Africa region established in 2005. There are 11 member countries as of July 2019, including Uganda, Kenya, Sudan, Ethiopia and Egypt.

Table 9: Examples of electricity and energy agreements related to export suspension

Examples of restrictions on measures	Name of agreements and summary of regulations
Limitation of force majeure	Agreement between the Republic of Turkey and Georgia concerning cross-border electricity trade via Borcka-Akhaltsikhe interconnection line (2012), Article 9, Paragraph 2
	Force majeure shall be limited to: - Natural disasters - War between sovereign states where the relevant party has not initiated the war under the principles of international law, acts of terrorism, rebellion or insurrection - International embargoes against states other than the relevant party
Measures prohibited on grounds of disputes	Energy Charter Secretariat, Model Intergovernmental Electricity Agreement, Part 4
	Each country agrees that its obligations under this agreement and its commitment to the project activities continue irrespective of disputes, requests, or changes, etc. related to border or territorial disputes (including now and in the future). Any border or territorial disputes must not interfere with the related projects. The obligations in this agreement and other related agreements must not be changed on the grounds of a border or territorial dispute or its resolution.
Specification and limitation of grounds for measures	Agreement between the Azerbaijan Republic and Georgia on oil pipeline (1996), Article 2, Paragraph 1
	Based on the principle of the smooth distribution of goods and services, the governments of the countries must not discontinue or hinder oil distribution through facilities in their own territories. In addition, the governments of the countries must not hinder distribution in any way such as [⋯] except to take reasonable measures when operation of facilities constitutes a threat to public health, safety, property or the environment. Even in this case, the measures must be limited to the degree and time period necessary to remove the threat.
Specification of quantities, price terms when measures taken	North American Free Trade Agreement (NAFTA), Chapter 6: Energy and Basic Petrochemicals, Article 605
	Exports may be restricted only in the following cases, except as stipulated elsewhere. - Exports are not reduced relative to total exports for the most recent 36 month period - Prices are set equivalent to prices for domestic consumption (prices are not set at a high level by means of taxes or licensing fees, etc.) - The restriction does not disrupt the normal supply channels of the other country or normal proportions of export products
Limitations on grounds for measures and investigations of appropriateness	EU Directive 2009/72/EC (the third energy package), Article 42
	- "In the event of a sudden crisis in the energy market and where the physical safety or security of persons, apparatus or installations or system integrity is threatened, a Member State may temporarily take the necessary safeguard measures." (however, the measures must be the minimum necessary.) - Member states have a duty to notify the other member states and the European Commission in advance. - The European Commission may decide that the member state who took such safeguard must amend or abolish such measures.

Source: Renewable Energy Institute based on various sources (provided below)

First, the WTO agreement promoting free trade (General Agreement on Tariffs and Trade [GATT])[17] prohibits export suspension (and restrictions) in principle. The act of suspending exports potentially violates the general repeal of quantity restrictions, and when a specific import country is singled out among multiple import countries, it is potentially a violation of the most favored nation clause (treatment equivalent to the best terms provided to another country), and if the import country is given terms less favorable than domestic transactions, it is potentially a violation of the national treatment clause (treatment equivalent to the terms provided domestically). Export suspension is not allowed except in certain circumstances like war or to save lives.[18]

Next, the Energy Charter Treaty is a multilateral agreement specifically for trade and investment

17 Most countries treat electricity as a product and trade it under GATT rules. Japan does not currently treat electricity as a product, but this is thought to be because it has not been involved in trading electricity.
18 Refer to Article 20 (General Exceptions) and Article 21 (Security Exceptions) of the WTO agreement (GATT).

related to energy. Along with guaranteeing “freedom of transit”[19] related to interconnectors, there is a clause allowing a company to initiate international arbitration with respect to the partner country, and this is considered an effective means of facilitating the electricity trade. At the present time, in Northeast Asia, the treaty has only been ratified by Japan and Mongolia, but when international grid connections are built, Japan could encourage related countries to join the treaty.[20]

In addition to these, it would be possible to establish more stringent restrictions on export suspension in an international treaty for the electricity trade. For example, as shown in Table 9, there are examples of excluding wars started by the export country from force majeure clauses and bilateral treaties that expressly disallow territorial disputes as grounds for suspension. There is also an example that specifically clarifies the conditions of quantity and price when export restrictions are applied, and an example that establishes a framework when the grounds given are a supply-demand crunch or to secure grid stability through which a supranational institution investigates the appropriateness of the restrictions and can require them to be changed or revoked while certain safeguards are recognized.[21]

How the situation is handled when a dispute occurs is also important, and there are various examples. When there is a suspected violation of the WTO agreement, member countries can appeal the matter with the other country before a panel.[22] There are also examples in separate treaties that establish a body for handling disputes and examples of efforts to prevent disputes by establishing a joint committee to discuss issues. Many bilateral investment agreements recognize the right of a foreign company that has incurred damage to directly appeal to the partner country. [23]

In this way, for the electricity trade, there is a legal framework in place capable of minimizing arbitrary export suspension through multilateral trade and investment treaties as well as individual treaties related specifically to electric power. Enforcement of international treaties certainly has its limits and all acts of export suspension cannot necessarily be prevented with treaties alone. However, when Japan builds interconnectors, establishing such a legal framework will provide a certain level of deterrence and be capable of preventing disputes in advance; it would also be likely to lead to the formation of an international market.

Section 3: Energy security and international grid connections in the era of renewable energy

1) Transformation of the concept of energy security

The conclusions from the chapter thus far are that international grid connections contribute to energy security and that concerns over electricity exports being suspended, for Japan in particular, can be almost entirely ignored. Moreover, it should be emphasized that the discussion to this point is based on the traditional conception of energy security in the fossil fuel era.

Fossil fuels are heavily concentrated in politically unstable regions, so how to procure and

19 “Transit” assumes energy is transported by pipelines and transmission facilities between three or more regions (countries). “Freedom of transit” means that no discriminatory or unreasonable restrictions based on the point of departure or arrival can be placed on transport.。
20 China and South Korea are observers to the Energy Charter Treaty. Russia signed the treaty, but announced in 2009 it had withdrawn.
21 EU Directive 2009/72/EC (the third energy package), Article 42. The same provisions can be found in Articles 36 to 39 of the Energy Community Treaty.
22 There are no examples of disputes related to electricity itself being handled through the WTO’s dispute settlement process. Refer to Gudas, K. (2018, p. 36).
23 While the cause was a dispute surrounding joint operation of a nuclear power plant, there is an example of a power company in the import country (Croatia) initiating international arbitration for damage compensation from the country that did not export the electricity (Slovenia), and the claim was recognized. Hrvatska Elektroprivreda d.d. v. Republic of Slovenia (ICSID Case No. ARB/05/24) Retrieved from https://icsid.worldbank.org/en/Pages/cases/casedetail.aspx?CaseNo=ARB/05/24

transport them stably has been a vitally important issue. Importers are at the mercy of price fluctuations, and sea lane defense has been emphasized. There is a clear distinction between the “haves” and the “have nots”; the haves are in an utterly dominant position and energy flows unidirectionally in what could be called a zero-sum relationship.

By contrast, though some types are not distributed evenly, renewable energy is found in large quantities in many countries. If domestically produced, it does not need to be transported, and except for biomass, fuel costs are zero, and because it is not depleted, resources do not need to be contested. Both geopolitical risk and geological risk are eliminated. It is the ideal form of energy, but due to cost and other factors, its deployment had been limited.

However, over the past five years or so, the cost of solar PV modules and wind turbines have come down dramatically, and as a result large-scale deployment is accelerating even in developing countries (IRENA, 2019c); this is the whole premise of the Study Group’s discussions. In light of this, the concept of energy security will no doubt change. The fact that China is the world’s largest producer of wind and solar PV power is symbolic of this change. This is precisely why China created GEIDCO and is promoting the construction of international grid connections in Northeast Asia; it has been increasingly active in taking strategic actions from an energy security perspective.[24]

2) Importance of international grid connections in the renewable energy era

As a result, the only risks that remain are supply system related. When the emphasis is on the variability of renewable energy, it could be concluded that risk in this era will increase. However, in response, the countries of Europe have adopted comprehensive policies to raise the flexibility of the power system, and international grid connections are one means of accomplishing this.[25] International grid connections are much less a concern than they are a way to transform the energy security environment; a change of perspective is needed.

In such a world, going beyond the issue of energy security itself, there is the possibility that international relations themselves will become cooperative and plus-sum between regions. This is because all countries would be the “haves” and would require a certain degree of interchange. It is for this reason that the benefits of export suspension are minimal and its risk nearly nil. Climate change is a threat to all of humanity, and countries around the world have no choice but to cooperate with one another. Renewable energy is the most powerful means to this end, and the international grid connections that contribute to its deployment promote both the independence of individual countries and the formation of relationships of mutual reliance.

This thought is no mere dream. As discussed in IRENA (2019a) and other sources, with the large-scale deployment of renewable energy, a new world is emerging that is not dependent on the scramble for fossil fuels. This is international relations in the renewable energy era, and the problem of energy security as traditionally conceived will dissipate. Conversely, it has been noted that the new threats to energy security will be securing the rare metals necessary to manufacture cutting-edge technologies related to solar panels and storage cells as well as cyber attacks on international grid connections, which will increasingly utilize information technologies (IRENA, 2019a). Even with these threats, the country that stands to benefit the most from this change in the concept of energy security and that accordingly needs international grid connections is a country without fossil fuel resources: Japan.

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24 For example, according to Jaffe (2018), the Chinese government is strategically deploying renewable energy and electric vehicles on a large scale to counter, both in terms of energy security and industrial policy, the United States, which is becoming an exporter of oil and natural gas thanks to the shale revolution.

25 Along with inter-regional transmission operations, including international grid connections, pumped-storage hydropower, accurate prediction of output variations through weather forecasting, flexible balancing capacity for thermal power and other measures are being utilized in a multifaceted manner. Moreover, going forward, demand side balancing capacity (demand response) and infrastructure conversion (sector coupling) are expected to make further progress.

Conclusion

1) Conclusions of the report

This third-term report of the Asia International Grid Connection Study Group took up outstanding issues and investigated the broad socioeconomic benefits of international grid connections before considering the matter with respect to energy security concerns.

International grid connections increase economic transactions of electricity through trade, contribute to supply stability through the sharing of reserve capacity, and promote deployment of renewables because they mitigate output variability. Even in considering the case of a Japan-South Korea interconnection, electricity charges would go down, a system of emergency interchange would be created, and generation of carbon dioxide and air pollutants would be reduced. There would be concrete benefits. This conclusion has been generally noted in previous reports as well, but the analysis in Chapter 3 was intended to provide a more systematic understanding of the matter.

Concerns over energy security, as discussed in Chapter 4, can essentially be ignored by Japan. When electricity is exported and imported in limited amounts on the assumption of sufficient supply capacity domestically, the effects of exports being suspended by another country on political grounds is nearly nil and so the benefits to that country, too, are non-existent. And, in actual fact, as far as this study could find, there have been no cases of exports being arbitrarily suspended when the parties involved are developed countries in Europe or North America.

Rather, as deployment of renewable energy continues to expand worldwide, an era is arriving in which it will be unnecessary to assume unidirectional export/import of fossil fuels. The problem of climate change itself is becoming a security risk for all of humanity, and the world's countries need to cooperate in addressing it. International grid connections, which contribute to renewable energy deployment, are an effective means to this end, and for Japan in particular, with its low energy self-sufficiency, taking this on is an urgent necessity.

Because the global energy transition has begun, as shown in Chapter 2, even in geographically disadvantaged regions such as the UK and Spain, international grid connections are being expanded. As discussed in Chapter 1, China and South Korea's active pursuit of international grid connections can be thought of in the same context. Countries are competing to set new rules for international relations in Northeast Asia and on initiatives for decarbonized economies, and the move to build international grid connections is a part of this. The only country in Northeast Asia not currently taking a proactive stance toward international grid connections is Japan, and we should acknowledge this fact with a sense of crisis.

2) Recommendations for realizing international grid connections

Based on the entire report, we would make the following specific recommendations in particular.

The first is that the Japanese government should begin full-fledged, concrete discussions on international grid connections with the governments of neighboring countries, such as South Korea, Russia and China. With regard to individual interconnectors, feasibility studies, the format of investment and trade, and other factors should be proactively considered. This includes comprehensive cost-benefit analysis. In light of the considerable time it will take until an interconnector commences operation, now is not too early to begin discussions.

Second, the Japanese government should reconsider the nature of energy security going forward. How long will the fossil fuel era continue, how much momentum is behind deployment of renewable energy, and what are the opportunities and risks, both technologically and resource-wise? The concept of energy security should not assume the same large-scale imports of fossil fuels; rather, the concept should be redefined on the premise of an energy transition and Japan's strategy should be rebuilt as a part of this. It goes without saying that international grid connections would be positioned prominently in this strategy. As renewable energy deployment and international grid connections continue to expand, now is not the time to stand by and watch, claiming that the uncertainties involved are too great.

Third, domestic power system reforms need to be accelerated to a level equivalent to Europe. As touched on in Chapter 1, Japan's electricity market can still not be called competitive. There is only one legally unbundled transmission company and not a single company whose ownership rights have been separated; the grid restrictions are acute. If these conditions are allowed to continue, they would cancel out any benefits derived from international grid connections; truly penetrating power system reforms, as we have learned from Spain and elsewhere, are absolutely vital, including expansion of inter-regional transmission lines and wider areas for transmission companies.

Fourth, the government and OCCTO should draw up a long-term master plan related to the domestic and international transmission grid. A comprehensive long-term plan needs to be formulated with independent transmission companies, using the example of ENTSO-E and others. On the premise of large-scale deployment of renewable energy, the necessary extent and locations of the transmission grid need to be considered and a target set of 2050, for example, when decarbonization is required. Doing so would also enable international grid connections to be integrated with inter-regional transmission lines.

Even having read this far, there may be some who would cite the recent tensions between Japan and South Korea and conclude that international grid connections would of course be a security issue. The current era, however, is one of deeper economic interdependence, and neither country would be able to stop the enormous volume of trade with the other. The question, rather, is whether to continue to be resigned to the asymmetrical relations of the fossil fuel era or to proactively build international grid connections that foster mutual dependence in the new era of renewable energy. We are faced with the questions that entail no less than a paradigm shift in international relations.

The Study Group is determined to again strongly promote these conclusions and recommendations to the government, power companies and other parties involved as well as to the general public. Practical discussions need to continue taking place with related parties in South Korea and China so that Japan can establish international grid connections as soon as possible.

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