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RENEWABLE ENERGY INSTITUTE

South Korea

Low Renewable Energy Ambitions Result in High Nuclear and Fossil Power Dependencies

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Renewable Energy Institute (REI)

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Table of Contents

List of Charts

List of Tables

Introduction

South Korea is both one of the world's largest economies (11th based on gross domestic product)[1] and energy consumers (8th based on total primary energy consumption)[2]. Until now, the economic development of the country has mostly been based on imported polluting fossil fuels (83% of total primary energy consumption in 2022)[3]. However, considering the ongoing global energy security and environmental crises, as well as South Korea's objective of reaching carbon neutrality by 2050, continuing this path is unreasonable.

In South Korea like everywhere else, the decarbonization of the energy system starts with the decarbonization of the power sector. This is because, compared to the heating & cooling and transport sectors, the power sector is the sector where alternatives to fossil fuels are the most economically and technologically mature.

In South Korea the two main solutions pursued for the decarbonization of the power sector are nuclear and renewable energy. While the country has managed to establish itself as a world leader in nuclear power, it has not yet succeeded in significantly expanding renewable energy electricity. Indeed, in 2022, whereas the share of nuclear power in South Korea's electricity generation mix was 29.6%, that of renewable energy was only 8.9%[4].

In January 2023, the government of South Korea released its biennial master plan, so called "Basic Plan for Long-Term Electricity Supply and Demand" (10th edition)[5]. With targeted renewable energy shares of 21.6% by 2030 and 30.6% by 2036, this plan is unambitious.

Despite these unambitious targets, implemented policy mechanisms supporting renewable energy (e.g., renewable portfolio standard, renewable energy certificates…) are worth presenting. Furthermore, the recent commitments of large South Korean corporate buyers (e.g., Samsung Electronics, Hyundai Motor Company…) to procure 100% of their electricity needs from renewable energy are encouraging signs that also deserve attention.

Finally, it is important to stress that the South Korean government's lack of ambitious plans for renewable energy unnecessarily prolong the country's problematic heavy reliance on nuclear and fossil power.

With this report Renewable Energy Institute aims at providing practical information about the latest key developments in South Korea's power sector to Japanese stakeholders. South Korea's geographical proximity and striking similarities with Japan makes it an interesting case study, even more at a time when diplomatic relationships between the two countries are improving.

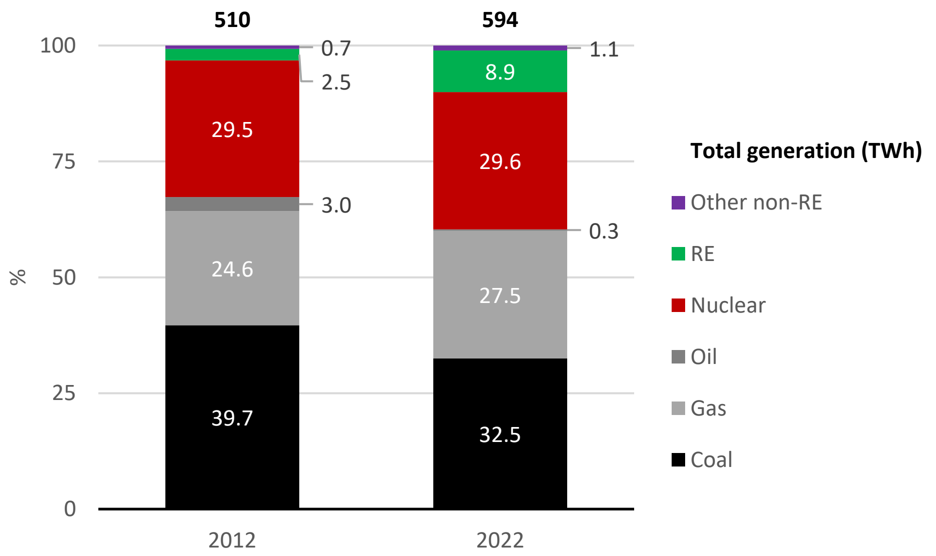
Chapter 1: Government Plans to Remain a Renewable Energy Laggard

Despite significant growth in solar photovoltaic installed capacity in the past decade (more than 20 gigawatts added between 2012 and 2022), the share of renewable energy in South Korea's electricity generation mix reached only 8.9% in 2022. The current government plans to increase this share to 21.6% in 2030 and 30.6% in 2036. This planned increase is insufficient to catch up with other developed countries. Therefore, for South Korea not to remain a renewable energy laggard, more ambitious plans need to be adopted. These plans should include solutions to overcome the four challenges renewable energy is confronted with in this country: suboptimal natural conditions, rather high generating costs, subsidized retail electricity prices, and social opposition.

1) Slow progress

The share of renewable energy (RE) in South Korea's electricity generation mix grew from 2.5% in 2012 to 8.9% in 2022, an increase of 6.5 percentage points (Chart 1). This result compares poorly with global progress, especially those observed in the other OECD (Organization for Economic Co-operation and Development) countries where the share of RE in electricity generation rose from 21.1% to 32.7% in the same period[6].

Chart 1: South Korea Electricity Generation Mix 2012 and 2022



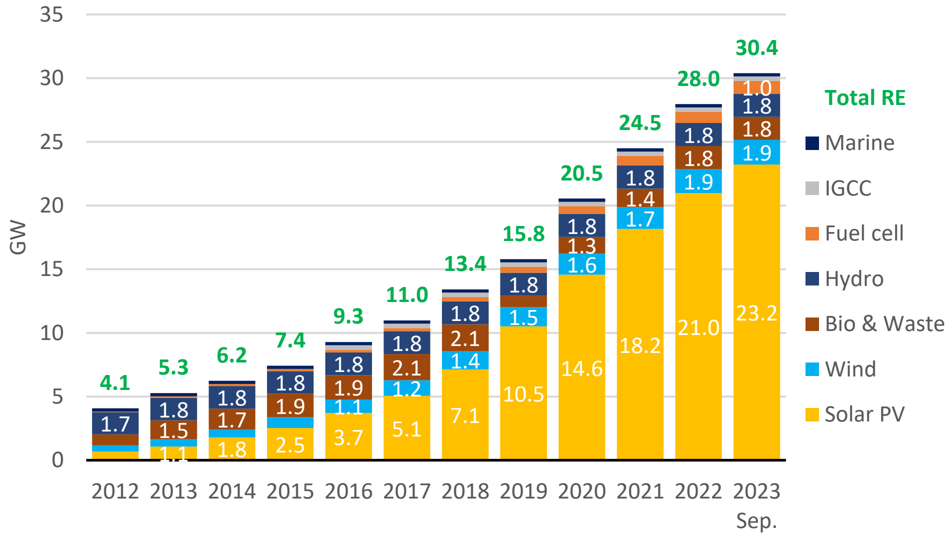
Notes: "RE" includes bioenergy & renewable waste, fuel cell, hydro, IGCC, marine, solar PV, and wind. "Other non-RE" includes pumped storage hydro and unspecified.

Source: Korea Electric Power Corporation, The Monthly Report on Major Electric Power Statistics – June 2023 (August 2023) [in Korean].

In South Korea the growth in RE electricity generation mainly came from solar photovoltaic (PV). In 2012 each RE technology accounted for around 1 gigawatt (GW), and in September 2023, only solar PV increased to 23 GW while the others remained below 2 GW (Chart 2).

In addition, in South Korea fuel cell (using the chemical energy of a fuel – most commonly gas reformed to grey hydrogen – to generate electricity) and integrated (coal) gasification combined cycle (IGCC, using a gas produced by a gasifier and steam turbines to generate electricity) are included together with RE technologies. This is because in South Korea “RE” is referred to under the terminology “new and renewable energy” which includes both new non-RE technologies (e.g., fuel cell and IGCC) and ordinary RE technologies (i.e., bioenergy & renewable waste, geothermal, hydro, marine, solar PV, and wind). The contributions of fuel cell and IGCC are minor: as of September 2023, 1.0 GW and 0.3 GW, respectively.

Chart 2: South Korea Cumulative RE Installed Capacity 2012-2023 September



Note: Capacity below 1 GW is not displayed for readability purposes.

Source: Electric Power Statistics Information System, Generation Capacity: By Fuel (accessed October 2, 2023).

2) Lack of ambition

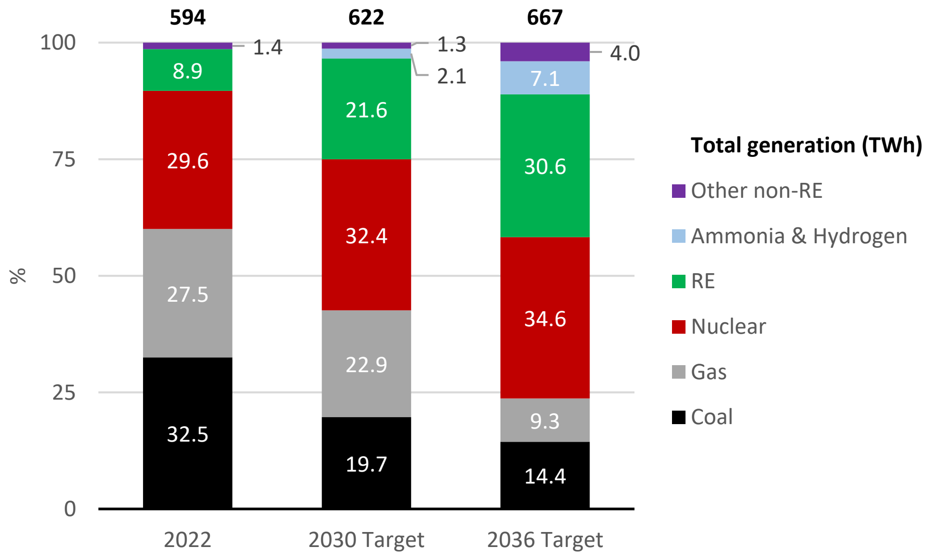
Based on the latest biennial master plan of the government, the Basic Plan for Long-Term Electricity Supply and Demand (10th edition, covering the period 2022-2036) released in January 2023, RE expansion is set to remain modest in South Korea.

This plan targets the share of RE in the country’s electricity generation mix to reach 21.6% in 2030 and 30.6% in 2036 (Chart 3 on next page). These objectives are unambitious and insufficient to catch up with other developed countries. In comparison, for example, even Japan – which is not an advanced country in terms of RE deployment – targets a RE share of 36-38% in fiscal year (FY, from April 1st to March 31st) 2030. Therefore, the plan of the South Korean government is that the country remains a RE laggard.

It may also be noted that the 2030 RE target of 21.6% is much lower than the 30.2% South Korea pledged in its Nationally Determined Contribution (NDC) in 2021, but it is slightly higher than the 20.8% aimed for in the country's 9th edition of the Basic Plan for Long-Term Electricity Supply and Demand adopted in 2020 (covering the period 2020-2034)[7]. To keep its NDC pledge consistent in terms of greenhouse gas (GHG) emissions from the power sector, the decrease in decarbonized electricity from RE is mainly planned to be offset by an increase in decarbonized electricity from nuclear. Indeed, from the NDC to the Basic Plan for Long-Term Electricity Supply and Demand (10th edition) the 2030 nuclear power target has been increased from 23.9% to 32.4%[8].

Because of its unambitious RE targets, the South Korean government plans to keep heavily relying not only on nuclear but also coal and gas power. The outlooks for these technologies are focused on in Chapter 3 "Problematic Continuous Reliance on Nuclear and Fossil Power" (pages 26-35).

Chart 3: South Korea Electricity Generation Mix 2022, and 2030 & 2036 Targets



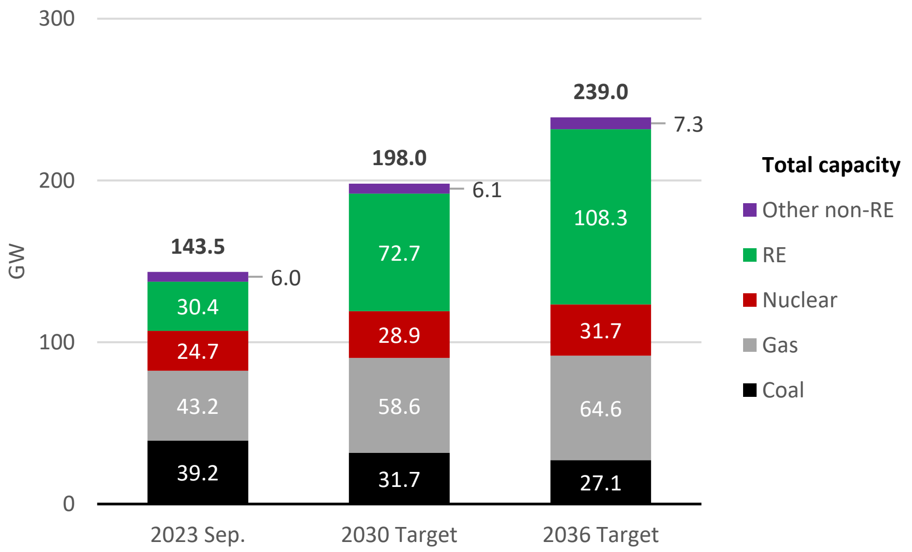
Notes: "RE" includes bioenergy & renewable waste, fuel cell, hydro, IGCC, marine, solar PV, and wind. "Other non-RE" includes oil, pumped storage hydro, and unspecified.

Sources: For 2022; Korea Electric Power Corporation, The Monthly Report on Major Electric Power Statistics – June 2023 (August 2023) [in Korean]. For 2030 and 2036 targets; South Korea Ministry of Trade, Industry and Energy, Basic Plan for Long-Term Electricity Supply and Demand – 10th edition (January 2023) [in Korean].

In addition to targeted electricity generation shares by power generating technology, the Basic Plan for Long-Term Electricity Supply and Demand also sets goals for cumulative installed capacity by power generating technology.

Among all power generating technologies, RE installed capacity is planned to grow the most: from approximately 30 GW in September 2023 to 73 GW in 2030 and 108 GW in 2036 (Chart 4 on next page). Yet, even by 2036 the majority of the country's installed capacity will remain fossil (mostly gas and coal) and nuclear power.

Chart 4: South Korea Cumulative Installed Capacity 2023 September, and 2030 & 2036 Targets



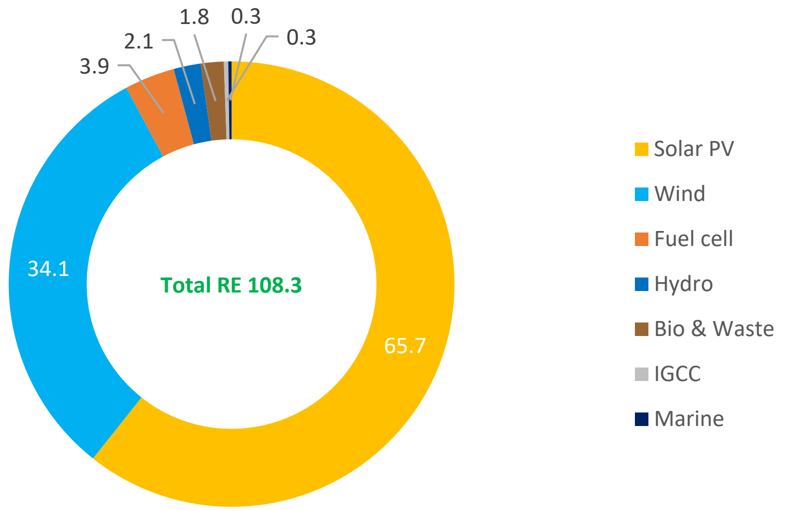
Notes: "RE" includes bioenergy & renewable waste, fuel cell, hydro, IGCC, marine, solar PV, and wind. "Other non-RE" includes oil, pumped storage hydro, and unspecified.

Sources: For 2023 September, Electric Power Statistics Information System, Generation Capacity: By Fuel (accessed October 2, 2023). For 2030 and 2036 targets; South Korea Ministry of Trade, Industry and Energy, Basic Plan for Long-Term Electricity Supply and Demand – 10th edition (January 2023) [in Korean].

The Basic Plan for Long-Term Electricity Supply and Demand also indicates the projected breakdown of cumulative RE installed capacity.

For instance, it forecasts that by 2036 the sum of solar PV and wind will account for 92% of RE installed capacity (Chart 5). This means that other technologies are expected to play a small role in the expansion of RE in South Korea.

Chart 5: South Korea Cumulative RE Installed Capacity 2036 Target (GW)



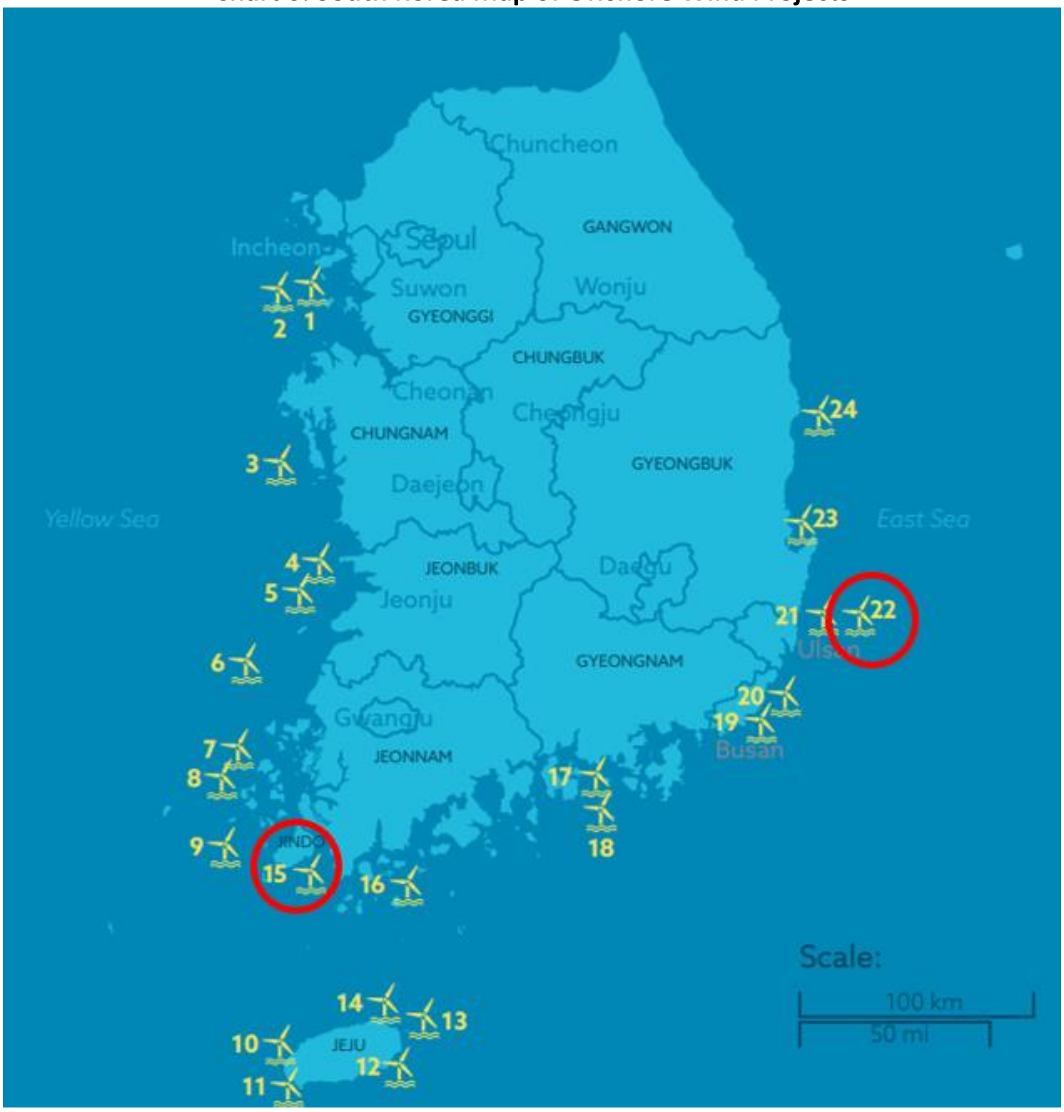
Source: South Korea Ministry of Trade, Industry and Energy, Basic Plan for Long-Term Electricity Supply and Demand – 10th edition (January 2023) [in Korean].

Regarding wind power targets, the Basic Plan for Long-Term Electricity Supply and Demand does not divide between on- & off-shore wind installed capacity – except for the year 2030: onshore wind 5 GW and offshore wind 14.3 GW[9]. South Korea's 2030 target for offshore wind installed capacity is 2.5 higher than of Japan for FY 2030: 5.7 GW.

As of the end of 2022, South Korea had installed only 0.1 GW of offshore wind capacity[10]. Nonetheless, 24 projects totaling a little more than 20 GW are being developed. These include two mega projects: the 8.2 GW "South Korea Government Project" and the 6.1 GW "Offshore Wind Projects in Ulsan" (Chart 6, projects #15 and #22, respectively).

The average conditions for offshore wind are particularly favorable in the sea south of the country: wind speed exceeding 7 meters (m) per second (at 80 m height), short distance from the shore – around 10 kilometers (km), and shallow water depth of 5-30 m enabling the use of bottom-fixed wind turbines (i.e., floating wind turbines are unnecessary)[11]. This explains the concentration of most projects in this geographical area.

Chart 6: South Korea Map of Offshore Wind Projects



Note: Red circles added by Renewable Energy Institute.

Source: Orrick, Global Offshore Wind Report: A Jurisdiction by Jurisdiction Update and Outlook 2022/2023 (December 2022).

The 8.2 GW South Korea Government Project is a project of the government (promoted by the previous government – under the presidency of Moon Jae-in, and continued by the current government – under the presidency of Yoon Suk-yeol), mainly led by the state-owned vertically integrated utility Korea Electric Power Corporation (KEPCO)[12]. This project is located in the sea southwest of the country. It is planned to be carried out sequentially in three phases: 4.1 GW between 2020 and 2025, 2.1 GW between 2022 and 2027, and 2 GW between 2024 and 2030. Bottom-fixed wind turbines will be used.

The 6.1 GW Offshore Wind Projects in Ulsan is a project of Ulsan City (supported by the previous mayor Song Chul-ho, and opposed by the current mayor Kim Doo-gyeom), conducted through collaboration with domestic and foreign companies (e.g., Equinor, Shell…)[13]. This project is located in the sea east of the country. It is planned to be commissioned by 2030. Due to water depth exceeding 50 m, floating wind turbines are necessary. Since the current mayor opposes this project, there is a political risk which could result in delays[14]. This is because permissions are required from the municipal government.

For South Korea to meet its 2030 offshore wind target, it is important that these two key projects progress smoothly.

3) Four challenges to overcome

In South Korea RE needs to overcome four challenges: suboptimal natural conditions, rather high generating costs, subsidized retail electricity prices, and social opposition. To some extent each of these challenges can be addressed. Advancing adequate solutions is critical for realizing the full potential of RE and going beyond unambitious governmental plans.

• Suboptimal natural conditions – Taking advantage of all opportunities

Like Japan, South Korea is confronted to particular natural constraints making it more challenging to deploy solar PV and wind than in most countries.

For example, while the country's landmass is rather small (0.1 million square km – almost four times smaller than Japan) its population is relatively big (52 million)[15]. This translates into a population density of more than 500 people per square km – the highest among OECD countries[16].

Moreover, 70% of the country's landmass is hilly and mountainous, with the remaining flat land dominated by large cities like Seoul, Busan, and Incheon[17]. This means the availability of suitable land for ground-mounted solar PV is limited. The construction of ground-mounted solar PV power plants has sometimes caused unsatisfying deforestation.

Furthermore, when it comes to offshore wind, in some places because of the depth of the sea, floating wind turbines which are less mature and more expensive than bottom-fixed wind turbines are necessary (e.g., in the east side of the country).

Nonetheless, the Ministry of Trade, Industry and Energy and the Korea Energy Agency (i.e., a governmental agency) estimated the country's solar PV market potential (i.e., the potential that can be developed on a cost-competitive basis after incorporating both technical constraints and realistic levels of government support) at 495 terawatt-hours (TWh) per year, and that of offshore wind at 119 TWh per year[18]. The sum of these market potentials is 614 TWh per year, or 92% of South Korea's projected total electricity generation in 2036.

In other words, the country's RE potential is significant, it is just more challenging to harness than in other countries. Thus, it should not be possible for the South Korean government to use the country's suboptimal natural conditions as an excuse not to advance more ambitious RE plans.

Having recognized the suboptimal natural conditions their country is confronted with, policymakers have started to advance solutions to promote various types of complementary RE solutions taking into account national circumstances.

The existing support mechanisms cover various types of technologies considering site conditions/fuels/performances, and/or system sizes. For instance, solar PV, ground-mounted, rooftop, floating, and forest projects all benefit from incentives, which are differentiated. This approach is also followed for wind power with onshore wind, coastal offshore wind (i.e., inside tidal flats and seawalls), and maritime offshore wind all being offered incentives, again differentiated incentives.

These mechanisms are useful, but their efficiency may be optimized by simplifying them. For the small-scale solar PV feed-in tariff (FiT) scheme, continuity is another issue. It has recently been officially announced that this program launched in July 2018 for a period of five years will not be extended further and be abolished according to the original plan[19].

The functioning of these somewhat complicated mechanisms is explained into detail in Chapter 2 "Solutions Advanced for the Expansion of Renewable Energy", section 2) "Auctions & small-scale solar photovoltaic feed-in tariff" (pages 18-20) and in Annex A "Renewable Energy Certificates" (pages 37-39).

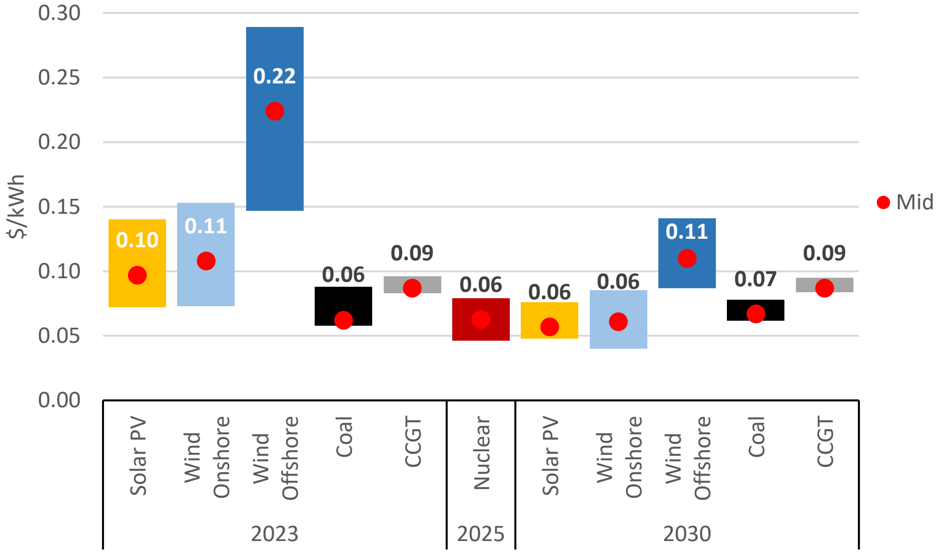
- High generating costs – Taking into account future cost decreases

The levelized cost of electricity (LCOE) of new solar PV, on- & off-shore wind in South Korea are among the highest in the world. Unlike in most countries (including Japan), new RE in South Korea is not the cheapest source of electricity.

The two major obstacles to overcome to improve the cost competitiveness of RE projects in South Korea are prolonged permitting processes and delayed grid connections. These two obstacles unnecessarily, artificially increase the LCOE of RE projects.

BloombergNEF expects that these obstacles could be overcome in a few years which will help significantly reduce the LCOE of new solar PV, and on- & off-shore wind in South Korea. Then, these key RE technologies would be cost competitive against new nuclear and fossil power (Chart 7).

Chart 7: South Korea LCOE of Selected New Power Generating Technologies



Notes: For all technologies except nuclear, the year indicated is the construction start year. For nuclear, the year indicated is the commissioning year.

Sources: For all technologies except nuclear; BloombergNEF, Levelized Cost of Electricity 2023 H1 (June 2023) [subscription required]. For nuclear; International Energy Agency, Projected Costs of Generating Electricity 2020 (December 2020).

It must be noted that whereas BloombergNEF's estimates are for construction start years, that of the International Energy Agency (IEA) is for commissioning year. It is assumed that in South Korea it takes one year to build solar PV plants, two years for on- & off-shore wind farms, four years for coal power plants, and three years for combined-cycle gas turbines (CCGT).

The estimate for nuclear power includes construction, fuel, O&M, decommissioning, and waste management costs, and it assumes an 85% capacity factor (which is in line with actual historical capacity factors observed in South Korea) (see also Chapter 3 "Problematic Continuous Reliance on Nuclear and Fossil Power", section 1) "Nuclear power: a decent track-record tarnished by safety issues" on pages 26-32). The LCOE of new nuclear power in South Korea is in the same range as that of new nuclear power in China, another country that keeps continuously building new reactors[20].

Thus, though RE currently suffers from being relatively expensive in South Korea, taking into account projected future cost decreases is important to recognize their true economic potential. The South Korean government should be more outspoken in communicating this positive message to electricity consumers.

- Subsidized retail electricity prices – Reforming an unsustainable situation

South Korea started reforming its electricity system in 1999. In 2001, KEPCO's generating arm was restructured into six separate wholly owned power generation subsidiaries: Korea East-West Power, Korea Hydro & Nuclear Power, Korea Midland Power, Korea South-East Power, Korea Southern Power, Korea Western Power (totaling 58% of the country's installed capacity as of September 2023), and the entry of independent power producers was allowed[21].

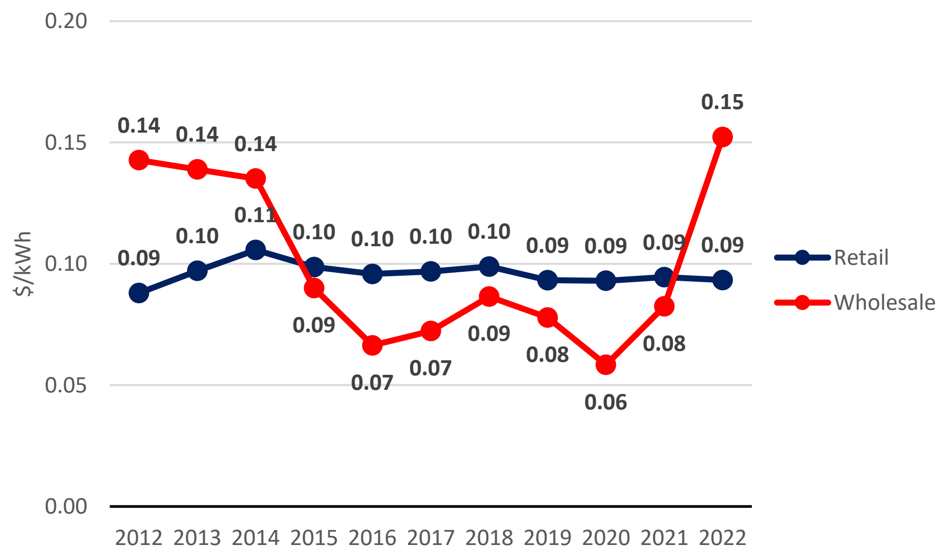
In addition, KEPCO remained the country's monopoly company for the transmission, distribution, and supply of electricity. While KEPCO is responsible for the management of transmission facilities as the asset owner, Korea Power Exchange is the independent transmission system operator.

Limited competition in the generation segment, and a monopoly situation in the supply segment deter or make it impossible for new entrants with new business models to participate in the electricity market. Such a framework hinders RE growth. This is because investments in RE usually mainly comes from new entrants, rather than from incumbents protecting their vested interests and conventional assets.

As a result of South Korea's insufficient electricity system reform progress, KEPCO still plays a central role in the country's power sector. Since KEPCO is a state-owned company, it is also a strategic tool to directly implement governmental energy policies, including retail electricity prices. Retail electricity prices are politically decided, and they are subsidized.

In South Korea it is not rare that retail electricity prices are below wholesale prices (Chart 8). This is illogical since retail prices should include wholesale prices (reflecting generating costs on the power exchange), transmission, distribution, and supply costs.

Chart 8: South Korea Wholesale VS. Retail Electricity Prices 2012-2022



Sources: For wholesale; Electric Power Statistics Information System, Electricity Market: Weighted Average SMP (accessed August 21, 2023). For retail; Korea Electric Power Corporation, The Monthly Report on Major Electric Power Statistics – June 2023 (August 2023) [in Korean].

Subsidizing retail electricity prices slow down the expansion of RE in two main ways:

First, it makes it more difficult for small-scale solar PV – a key technology of the energy transition – to reach socket parity (i.e., when the LCOE of small-scale solar PV is less than or equal to retail electricity prices). Economic competitiveness is a decisive factor when arbitrating between buying electricity from a supplier or investing in small-scale solar PV for self-consumption. In South Korea, consumers' choice is biased by the government's regulation of prices.

Second, maintaining artificially low retail prices severely weakens the financial position of KEPCO. The energy transition requires significant investments in RE and grid infrastructures. If KEPCO cannot proceed with such investments because of its economic fragility, the energy transition of South Korea's power sector will be blocked. As of the end of 2022, KEPCO was heavily indebted: $149 billion[22]. This is problematic.

Therefore, because subsidizing retail electricity prices is unsustainable, the government of South Korea should courageously reform its pricing policy.

The South Korean government recently agreed to raise retail electricity prices. They reached $0.11/kilowatt-hour (kWh) in the first half of 2023; a 21% increase compared to 2022[23]. This is a step in the right direction. Yet, it is insufficient because retail prices are still well-below wholesale prices, which ranged between $0.11/kWh and $0.20/kWh on a monthly basis between January and June 2023[24].

- Social opposition – Building Consensuses

With low lifecycle GHG emissions, RE technologies are intrinsically clean from a decarbonization perspective. Moreover, unlike nuclear power, they do not produce harmful spent fuel and radioactive waste which management is arduous. Despite these undeniable environmental advantages, RE often faces social opposition in South Korea.

In rural areas the visual impact of utility-scale solar PV and onshore wind is frequently criticized. Deforestation caused by some ground-mounted solar PV projects understandably caused public backlash. Fishermen are concerned about the emergence of multiple offshore wind projects on their activities.

Unless RE is located near demand centers, the integration of RE into power systems also requires new electrical grid infrastructure. These may also be opposed.

Because of social opposition RE projects may be delayed, worse they also face the risk of being cancelled. Therefore, it is important to correctly address this acute issue. In South Korea, the need for action is well-recognized. Worthwhile efforts have been being pursued and need to be further developed.

For example, to support alternatives to ground-mounted solar PV, the South Korean government offers higher incentives to floating and rooftop solar PV which generally face less opposition from local communities. Conversely, solar PV projects located in forest areas receive the lowest incentives (see also Annex A "Renewable Energy Certificates" on pages 37-39).

In addition, to encourage the participation of local communities in the recently discontinued FiT scheme for small-scale solar PV, the capacity ceiling of projects was increased for specific categories of owners. If the plant was owned by a government-registered farmer, fisherman, livestock raiser, or cooperative, the capacity ceiling of the program was <100 kilowatts (kW) instead of <30 kW[25] (see also Chapter 2 "Solutions Advanced for the Expansion of Renewable Energy", section 2) "Auctions & small-scale solar photovoltaic feed-in tariff" on pages 18-20).

As for wind power, the situation is more complicated as no clear set of domestic solutions has been established so far. However, to facilitate the adoption of offshore wind, a legislative proposal that site development should be government-led has emerged[26].

Finally, when it comes to electrical grid infrastructures, the South Korean government received the demand of local communities that new transmission facilities be installed underground, and it committed to increase the involvement of residents early on in the site selection process[27].

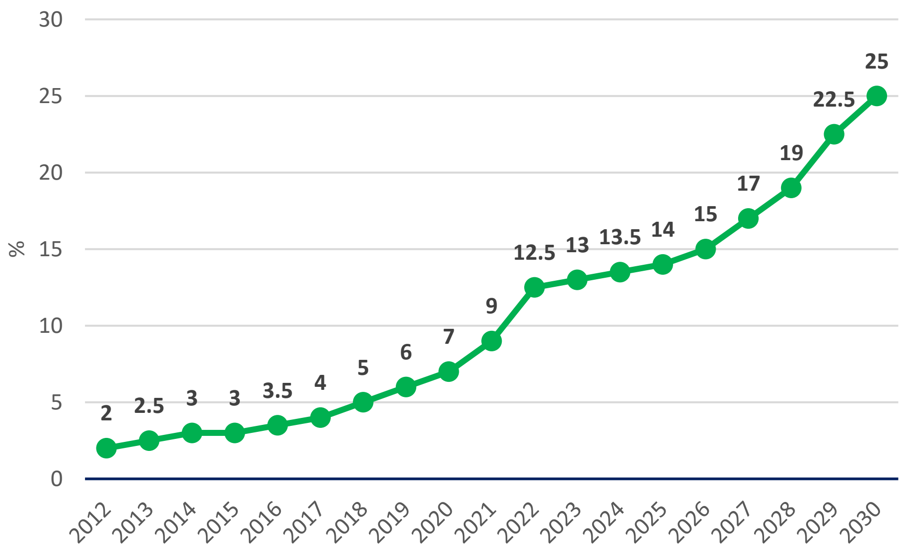
Chapter 2: Solutions Advanced for the Expansion of Renewable Energy

To reach its renewable energy targets South Korea mainly relies on a renewable portfolio standard. In this framework, renewable energy certificates play a key role as a source of income for renewable energy generators and as a means of promoting various technologies. In recent years, auctions and a feed-in tariff for small-scale solar photovoltaic also contributed to renewable energy growth. To ensure a successful integration of renewable energy into the electrical network, South Korea pursues battery storage to keep supply and demand in balance, and domestic power grid expansion to transport offshore wind power to demand centers. Pioneering companies also play an important role in the rise of renewable energy in South Korea. Green tariffs is currently the most popular renewable energy procurement option among the four options used.

1) Renewable portfolio standard

The main policy tool implemented to support South Korea's target of reaching a RE share of 21.6% in electricity generation by 2030 is a renewable portfolio standard (RPS). Introduced in 2012, the RPS mandates power generators with installed capacity ≥500 megawatts (MW) (i.e., 25 companies which accounted for 72% of the country's total electricity generation in 2021) to increase the share of RE in their electricity to 25% by 2030 (Chart 9)[28].

Chart 9: South Korea RPS Trajectory 2012-2030



Source: Korea Trade-Investment Promotion Agency, Recent Trends on the Renewable Industry and Policy in Korea – May 3, 2023 (accessed August 22, 2023).

In April 2021, the previous government decided to increase the RPS requirement for 2022 from 10% to 12.5% to accelerate RE growth[29].

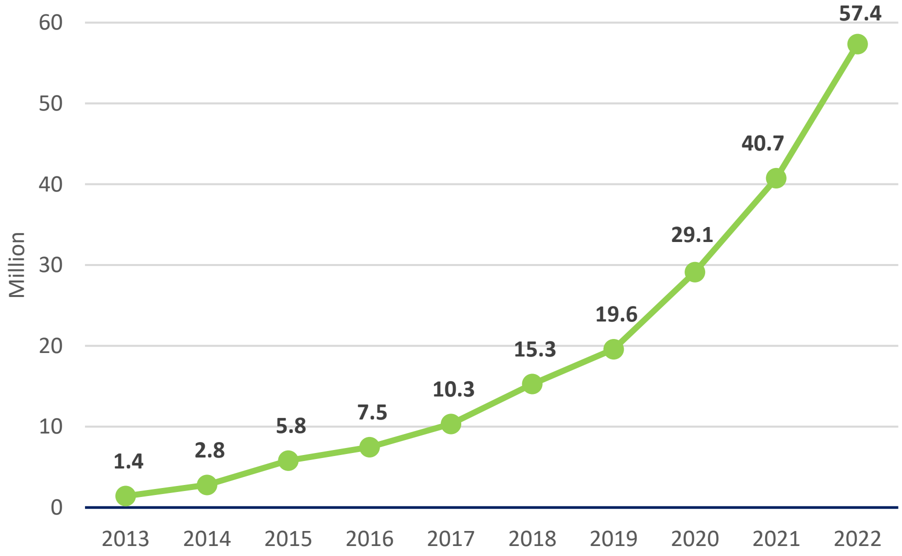
The obligation set by the RPS can be met either by generating RE electricity or by buying renewable energy certificates (RECs).

Failing to comply with the RPS requirement may result in administrative fines amounting to 1.5 times the average trading price of RECs[30].

A REC is a tradable commodity that is created by generating 1 megawatt-hour (MWh) of RE electricity. RECs are both a source of income for RE generators and a useful way to promote various technologies thanks to different certificate weights (see also Annex A "Renewable Energy Certificates" on pages 37-39).

The higher RPS requirements and the expansion of RE electricity generation have contributed to significantly increase the trading volume of RECs in South Korea: from 1.4 million in 2013 to 57.4 million in 2022 (Chart 10). In 2022, the trading volume of RECs was equivalent to 9.6% of the country's total electricity generation.

Chart 10: South Korea REC Trading Volume 2013-2022



Source: Korea Power Exchange, Electricity Market Statistics 2022 (July 2023) [in Korean].

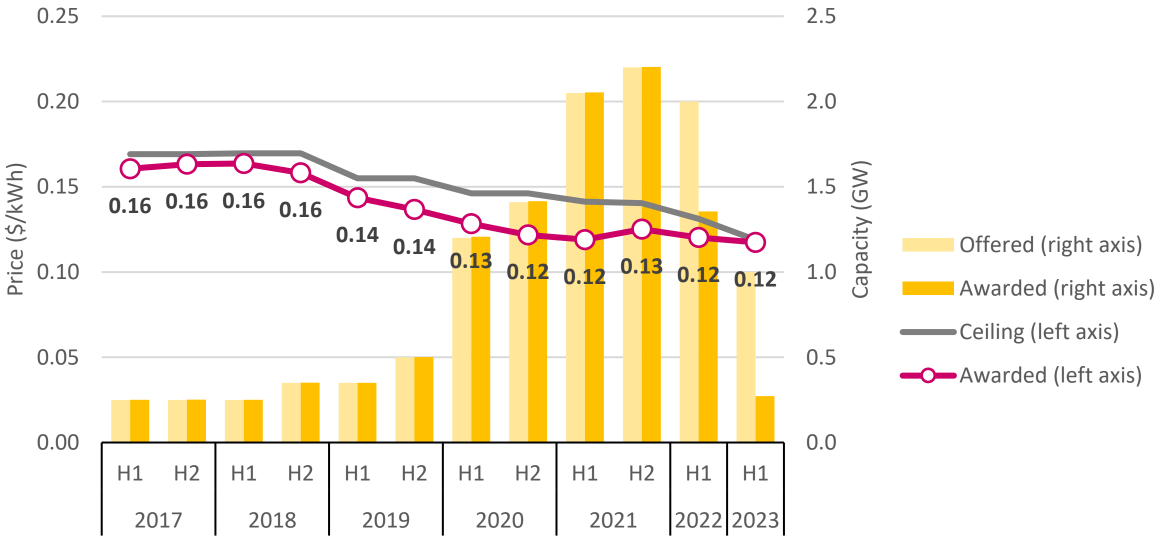
2) Auctions & small-scale solar photovoltaic feed-in tariff

To offer RE generators the possibility to seek stable revenues, solar PV auctions and a small-scale solar PV FiT scheme, both with long-term fixed-price contracts of 20 years, were introduced in 2017 and 2018, respectively. In 2022, an auction for wind power was organized for the first time.

- Auctions: successfully spurred solar photovoltaic growth

In recent years, solar PV auctions with long-term fixed-price contracts have been a major factor of solar PV growth in South Korea. In the twelve auction rounds organized between the first half of 2017 (2017 H1) and the first half of 2023 (2023 H1), a total of 11.8 GW of capacity was offered and 10.5 GW awarded, at prices decreasing from $0.16/kWh to $0.12/kWh (Chart 11).

Chart 11: South Korea Solar PV Auctions 2017 H1-2023 H1



Source: Korea RE100 Alliance, *Solar PV Auctions* (accessed August 24, 2023) *[in Korean].*

In the first ten rounds (2017 H1-2021 H2), all capacity offered was awarded. In the eleventh and twelfth rounds (2022 H1 and 2023 H1), of the 3 GW offered only 1.6 GW was awarded. This is because investors in solar PV projects estimated that it would be more profitable to sell their electricity in the wholesale and REC markets due to the high wholesale prices resulting from high fossil fuel prices. This arbitrage appears economically rational in the short-term at least.

On the one hand prices awarded in the eleventh and twelve rounds were $0.12/kWh – just below the auction ceiling prices. On the other hand, for example, the monthly revenue of a medium-size ground-mounted solar PV project of 100 kW-3 MW (which certificate weight is 1) selling its electricity in the wholesale and REC spot markets ranged between $0.14/kWh and $0.26/kWh in 2022.

As for wind power, in the first auction 550 MW of capacity was offered with a ceiling price of $0.13/kWh[31]. Sixteen bids totaling 712 MW were submitted (including one offshore wind project of 99 MW). After assessment, only eight bids with a combined capacity of 374 MW were selected. The government did not disclose details.

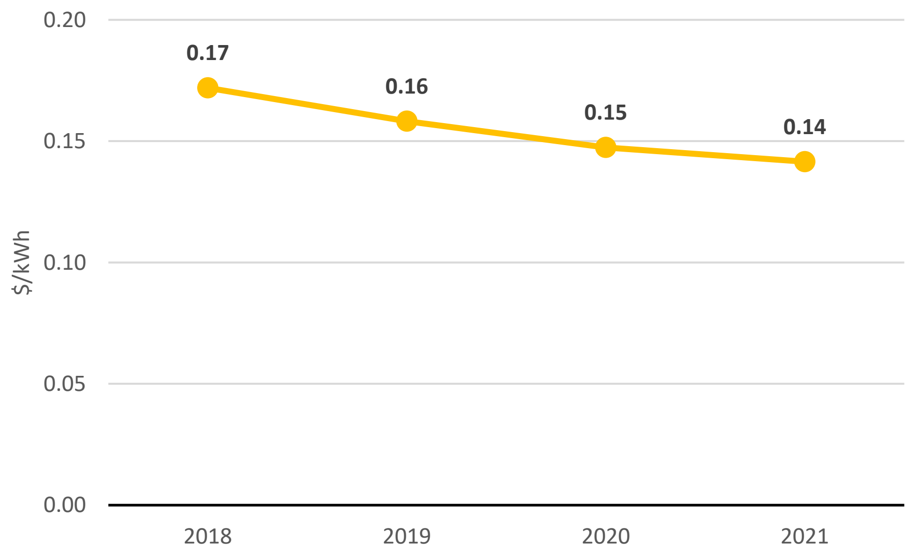
- Small-scale solar photovoltaic feed-in tariff: useful but discontinued

Launched in July 2018 for a period of five years, the FiT scheme for small-scale solar PV has recently been discontinued. This is because the South Korean government made the decision in July 2023 not to extend this program beyond its original expiry date[32]. This decision was notably motivated by illegal uses of subsidies in solar PV projects (i.e., mostly illegal loan execution, unlawful subsidy allocation, and bid rigging)[33]. Though there can be no excuse for fraudulent activities, it is regrettable that the discontinuation of this scheme leaves the segment of small-scale solar PV in limbo.

During its implementation period, the FiT scheme could stimulate investments in small-scale solar PV by offering simple and stable long-term fixed-price contracts of 20 years to projects <30 kW or <100 kW (if owned by a government-registered farmer, fisherman, livestock raiser, or cooperative). As of March 2023, 3.9 GW of small-scale solar PV capacity was registered under this scheme[34].

The contract price decreased from $0.17/kWh in 2018 to $0.14/kWh in 2021 (data for 2022 and 2023 could not be found), reflecting solar PV cost decrease (Chart 12).

Chart 12: South Korea Solar PV FiT Price 2018-2021



Source: South Korea Ministry of Trade, Industry and Energy, [The Amount of Support for the Korean FIT is Flexible Depending on the Average Successful Bid Price of Competitive Bidding and System Marginal Price]() (October 2021) [in Korean].

3) Electrical network integration

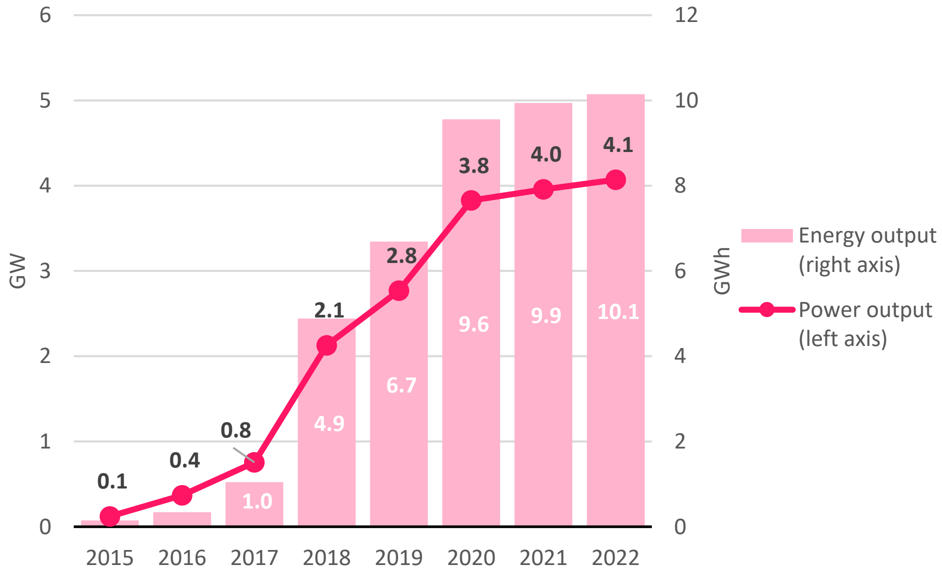
In South Korea the two main actions pursued to successfully integrate RE into the electrical network are the deployment of battery storage and the expansion of the domestic power grid. South Korea's grid is an isolated system with no cross-border transmission lines. The mainland area of South Korea and Jeju Island are interconnected via two high-voltage direct current (HVDC) submarine cables.

Until now RE curtailment has mostly been an issue in Jeju Island[35]. Wind power is the most affected by curtailment which is due to inflexible operations of fossil power plants[36]. No economic compensation is given for curtailment[37].

- Battery storage: increasingly contributing to supply and demand balance

South Korea is a world leader in battery storage deployment. In 2022, the country's battery storage cumulative installed capacity reached 4.1 GW [power output]/10.1 gigawatt-hours (GWh) [energy output] (Chart 13). In comparison, Japan's battery storage cumulative installed capacity was only 2.7 GW/6.4 GWh.

Chart 13: South Korea Battery Storage Cumulative Installed Capacity 2015-2022



Note: "Energy output" means the maximum amount of energy that can be stored and "Power output means" the total possible instantaneous discharge capability.

Source: BloombergNEF, Energy Storage Market Outlook 2023 H1: Ambitious Targets, Ambiguous Outlook (March 2023) [subscription required].

The growth of battery storage in South Korea has been especially spectacular between 2018 and 2020. This is because in this three-year period generous certificate weights were available for solar PV and wind paired with battery storage. For instance, for solar PV + battery storage the certificate weight was 5 then 4, and for wind the certificate weight was 4.5 then 4 (the changes of weights occurred in July 2020)[38].

This policy was discontinued because of fire incidents caused by, for examples, inadequate battery protective system, inadequate management of operating environment, and improper installation of battery storage system[39].

Despite this temporary setback, the South Korean government remains committed to significantly expand battery storage. In the Basic Plan for Long-Term Electricity Supply and

Demand, it is targeted that 24.5 GW/127.3 GWh of storage capacity (including battery storage and excluding pumped storage hydro) should be installed in the period 2023-2036[40]. Of this capacity, 20.85 GW/124.97 GWh should be long-duration systems (i.e., up to several hours) for RE curtailment reduction and load leveling, and 3.66 GW/2.29 GWh should be short-duration systems (i.e., up to 30 minutes) for frequency regulation.

The promotion of battery storage by the South Korean government is only partly motivated by considerations about the integration of RE into the national electrical network. Battery storage is also recognized as a high value-added industry which has a significant potential for export in the context of global decarbonization which is based on solar PV and wind[41]. As such, the domestic market serves as the testbed for battery storage technologies to be exported.

- Power grid expansion: transporting offshore wind power to demand centers

In May 2023, KEPCO announced the "Long-Term Transmission and Substation Plan"[42]. This Plan has been established in accordance with the Basic Plan for Long-Term Electricity Supply and Demand. Therefore, it also covers the period between 2022 and 2036. It contains information such as necessary domestic transmission grid expansion and reinforcement to integrate new power plants.

The emphasis is put on the development of a new HVDC corridor to transport electricity generated on the West Coast, where multiple new offshore wind projects such as the South Korea Government Project (see page 11) are located, to the demand centers in the northwest, where the country's capital Seoul is located[43]. There is no exact date specified for the realization of this corridor, but since the Long-Term Transmission and Substation Plan covers the period 2022-2036, it is understood that it should progressively be completed within the next 10-15 years.

Since KEPCO's Long-Term Transmission and Substation Plan does not include a map showing this corridor, for visualization purposes, a chart adding it has been created using an original map of the IEA (Chart 14 on next page).

Chart 14: South Korea Map of Transmission Power Grid with Vision of New Corridor Added

Note: Red arrow and blue circle, as well as accompanying text added by Renewable Energy Institute.

Source: International Energy Agency, Korea Energy Policy Review 2020 (November 2020).

4) Corporate buyers

South Korean companies are important players in global supply chains for key industries[44]. They increasingly face pressure from their global customers pursuing the decarbonization of their supply chains. Among international brands with ambitious commitments to decarbonize their entire supply chain, Apple, for example, relies on South Korean suppliers for semiconductors.

If South Korean companies cannot be supplied with enough RE electricity, it is inevitable that their competitiveness will be undermined in major markets like the United States and Europe[45]. This is a serious trade risk jeopardizing the country's future economic prospects.

Against this backdrop, pioneering companies are rising to the challenge in South Korea. Well-over 200 companies with economic activities in the country now have GHG emissions reduction targets[46]. Around 30 South Korean companies and 120 foreign companies with a presence in South Korea have joined the RE100 initiative (i.e., a global corporate voluntary initiative bringing together businesses committed to 100% RE electricity by 2050). Samsung Electronics and Hyundai Motor Company are examples of South Korean companies which are members of the RE 100 initiative.

This trend results in increasing RE electricity consumption which is critical to accelerate the growth of RE in South Korea, even more so considering the unambitious RE targets of the South Korean government.

For the time being, however, South Korea's RE procurement market is a seller's market and corporate buyers face two key obstacles in meeting their RE electricity needs[47]. First, the availability of RE electricity is limited due to slow expansion progress, and there is competition on the demand side between power generators under the RPS mandate and corporate buyers to access this limited supply. Second, the cost of RE in South Korea is high and inflated due to incentives (i.e., RECs). RE generators are unwilling to directly sell their electricity to corporate buyers unless the buyers are willing to match or exceed the incentives.

This situation is problematic for corporate buyers. The South Korean government needs to address these obstacles rapidly by adopting more ambitious RE targets and by finding ways of deploying RE electricity more cost-efficiently so that it becomes affordable.

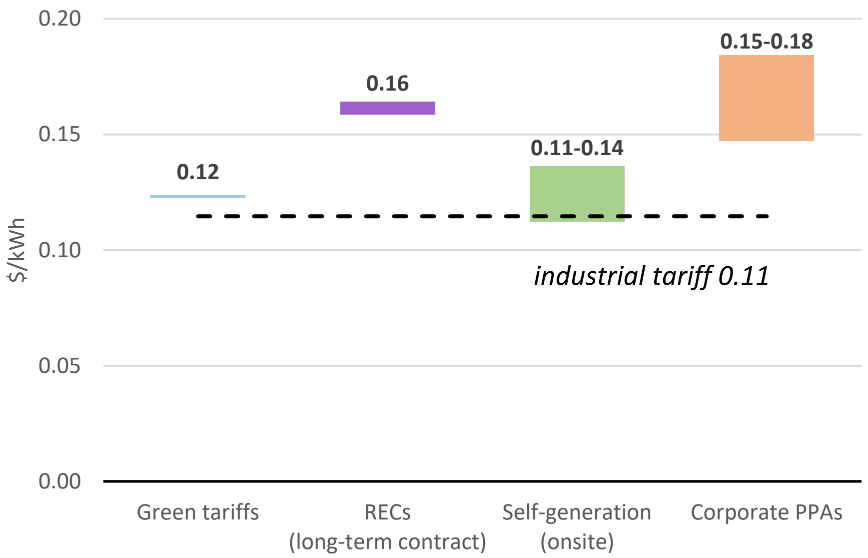
There are currently four types of RE procurement options being used in South Korea: green tariffs, RECs, self-generation, and corporate power purchase agreements (PPAs). Each of these options come with advantages and drawbacks in terms of complexity, cost, and additionality (i.e., positive impact on adding RE) (Table 1) (see also Annex B "Renewable Energy Procurement Options" on pages 40-43):

- Green tariffs and RECs are the simplest procurement options, and corporate PPAs is the most complicated one,
- Green tariffs and self-generation are the cheapest procurement options, and RECs and corporate PPAs are the most expensive ones (Chart 15 on next page), and
- Self-generation and corporate PPAs are the procurement options with the highest additionality, and green tariffs the one with the lowest additionality.

Table 1: South Korea Advantages and Drawbacks of RE Procurement Options

Procurement option	Complexity	Cost	Additionality
Green tariffs	low	low	low
RECs	low	high	middle
Self-generation	middle	low	high
Corporate PPAs	high	high	high

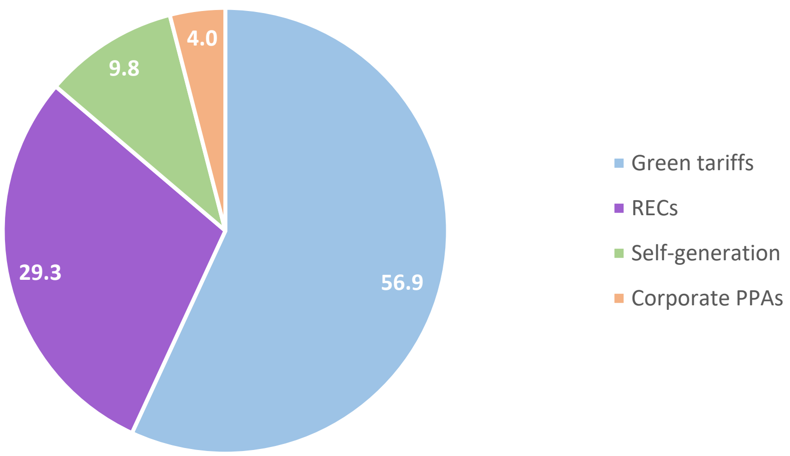
Chart 15: South Korea Costs of RE Procurement Options



Source: BloombergNEF, Korea Clean Power Procurement 101: Growing Demand, Limited Supply (July 2023) [subscription required].

As a result of these characteristics, green tariffs were the most popular RE procurement option in South Korea as of December 2022: 56.9% of RE procurement deals (Chart 16). They were followed by RECs which accounted for 29.3% of RE procurement deals. Finally, self-generation accounted for 9.8% of RE procurement deals, and corporate PPAs only 4.0%.

Chart 16: South Korea RE Procurement Deals Breakdown by Option Type, as of December 2022



Note: The total amount of electricity covered by these deals is undisclosed.

Source: BloombergNEF, Korea Clean Power Procurement 101: Growing Demand, Limited Supply (July 2023) [subscription required].

Chapter 3: Problematic Continuous Reliance on Nuclear and Fossil Power

Because of unambitious targets for renewable energy, the government of South Korea plans to keep heavily relying on nuclear and fossil power. Despite a rather successful strategy for deploying low-cost reactors, nuclear power further expansion is confronted with four major issues raising social concerns: developing new reactor sites, extending reactor lifespan, ensuring safety, and expanding spent fuel storage. Coal and gas power plants will still be operated, some of which will rely on cofiring coal with ammonia and others gas with hydrogen. These two cofiring technologies are immature. This means there is a high risk of carbon lock-in, even more so when the colors of the ammonia and hydrogen to be used are unspecified. Instead, more efforts should be dedicated to strengthening the country's emissions trading system by terminating free allocation of emissions allowances for the power sector and tightening the emissions cap.

1) Nuclear power: a decent track-record tarnished by safety issues

South Korea is a world leader in nuclear power with 25 reactors (24.7 GW) in operation and a share of 29.6% in electricity generation.

The South Korean nuclear power industry has historically been performant in building nuclear reactors relatively rapidly and at reasonable costs, as well as in operating them at high-capacity factors. This enabled nuclear power to economically outcompete other power generating technologies.

Despite this apparent decent track-record, nuclear power is a socially divisive issue in South Korea because of the technology's inherent safety risks. Over the past decade several safety issues have occurred eroding public trust. Distrust in nuclear power safety, as well as unsolved problems related to spent nuclear fuel and radioactive waste management were the reasons that led the previous government to adopt a nuclear power phaseout policy in 2017. The decision by the current government to overturn this phaseout policy in 2022 is not a blank check to the South Korean nuclear power industry that will need to convince the population of its trustworthiness.

- Strategies for low-cost reactors

When it started developing its nuclear power industry South Korea had the advantage that it did not start entirely from scratch. In the 1970s-1980s, South Korea imported proven reactor designs from Canada (CANDU 6), France (France CPI), and the United States (WH 60 and WH F), and it learned from other countries' experiences before developing its own domestic optimized reactor design: the OPR-1000. This reactor design served as a standard design and as such it was repeatedly constructed (i.e., 12 reactors), mainly in the 1990s-2000s.

The strategy implemented to efficiently advance nuclear power was to build reactors in pairs at single sites, and continuously add new pair of reactors at existing sites, which saves onsite related costs (e.g., evacuation plans) and makes it possible to consolidate control rooms. It also facilitates logistics since specialized equipment and workers stay at the same location.

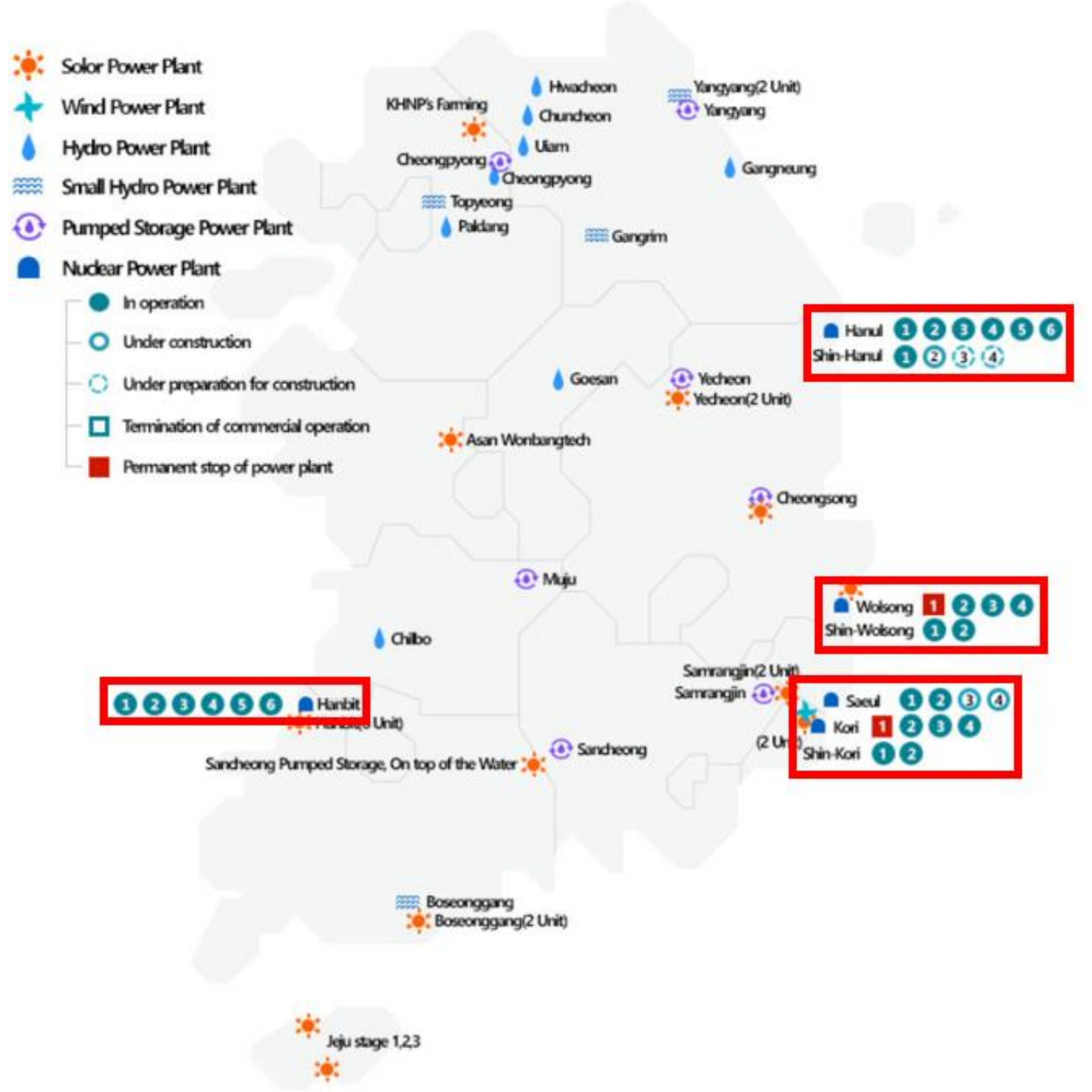
However, a drawback of this approach is that it makes it more difficult to contain an accident, increasing safety risks. This issue was pointed out at the time of the Fukushima nuclear accident in Japan in March 2011. Another drawback of this approach is that sudden outages at large-scale nuclear power plants have significant negative impacts on the operations of power systems (this also applies to large-scale coal and gas power plants).

This strategic approach never changed as all nuclear reactors in South Korea (including those in operation, as well as the three reactors under construction, and the two reactors permanently shut down) have been spread across only four different locations in the country: three on the East Coast; Gijang-gun/Ulsan (Kori-1 to -4, Shin-Kori-1 &-2, and Saeul-1 to -4), Gyeongju-si (Wolsong-1 to -4 and Shin-Wolsong-1 & -2), Ulchin-gun (Hanul-1 to -6 and Shin-Hanul-1 & -2), and one on the West Coast; Yeonggwang-gun (Hanbit-1 to -6) (Chart 17 on next page)[48].

Another important reason for this approach not to change is the social opposition to the construction of nuclear reactors at new sites. For instance, the new sites of Samcheok and Yeongdeok were designated to host nuclear power plants in 2012, but these plans were cancelled in 2018 because local residents strongly opposed these projects[49].

This limits prospects for nuclear power as it will not be possible to continuously expand existing nuclear power plants. Recognizing this issue, policymakers are also now encouraging lifespan extension of nuclear reactors. This can only be a temporary solution. A solution for which the domestic nuclear power industry lacks experience (i.e., no nuclear reactor has ever been operated beyond 40 years in South Korea).

Chart 17: Korea Hydro & Nuclear Power Map of Power Plants, as of June 30, 2023



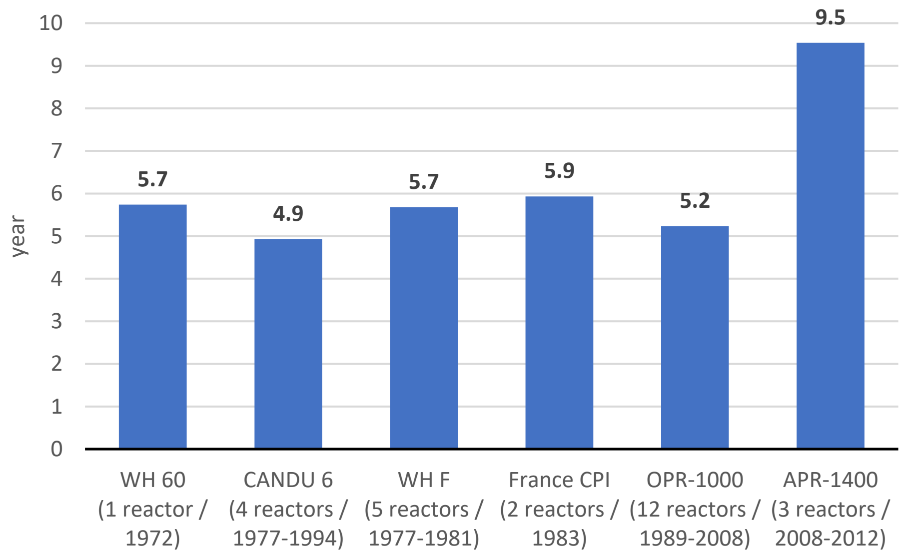
Notes: Red boxes added by Renewable Energy Institute. Though the Kori & Shin-Kori reactors are officially located in Gijang-gun and the Saeul reactors in Ulsan, their geographical proximity is so close (i.e., less than 1.5 km) that they are considered to be located together.

Source: Korea Hydro & Nuclear Power, Overview: Power Generation Facilities (accessed August 31, 2023).

South Korea has been successful in building nuclear reactors relatively rapidly, and at reasonable costs.

Except for the new APR-1400 design, the successor of the OPR-1000, it took on average about 5-6 years to construct all other reactor designs (Chart 18 on next page). The APR-1400 is an evolution of the OPR-1000 which main developments are enhanced safety, increased power output (from 1,000 to 1,400 MW) and theoretical lifespan (from 40 to 60 years)[50]. Regarding safety, the APR-1400 design may be deemed limited because it has no core-catcher (i.e., a device to retain the core of the reactor in the event of a core melt) and the reactor building only has a single containment structure (instead of a double one)[51].

Chart 18: South Korea Nuclear Reactors Actual Average Construction Time by Design



Note: Between parentheses are indicated the number of nuclear reactors built with the corresponding design, and the construction start years of the first and last reactors with the corresponding design.

Source: International Atomic Energy Agency, Power Reactor Information System: South Korea – updated August 29, 2023 (accessed August 30, 2023).

Relatively short construction periods combined with standardized and simple reactor designs resulted in reasonable construction costs of nuclear reactors in South Korea. In the case of the OPR-1000, construction costs were in the range of $2,000-2,600/kW[52]. In the case of the first two APR-1400 (i.e., Saeul-1 & -2 which started commercial operation in 2016 and 2019, respectively), the constructions cost was around $2,900/kW[53]. This is roughly at least 3.5-4.5-fold cheaper than the latest flagship nuclear reactor projects in France (i.e., Flamanville-3) and the United States (Vogtle-3 & 4).

Another achievement of the South Korean nuclear power industry is to have manage to operate almost all types of reactor designs at high-capacity factors. Excluding the design WH 60; Kori-1, the first ever commercial nuclear reactor in South Korea (1978-2017), all other designs reached remarkable average lifetime capacity factors: approximately 82%-87%[54].

Thanks to reasonable construction costs and high-capacity factors, nuclear power is currently the most competitive existing power generating technology in South Korea. At $0.05/kWh it clearly outcompetes bituminous coal and liquefied natural gas (LNG)-fired power plants, the country's two main other power generating technologies (Chart 19 on next page).

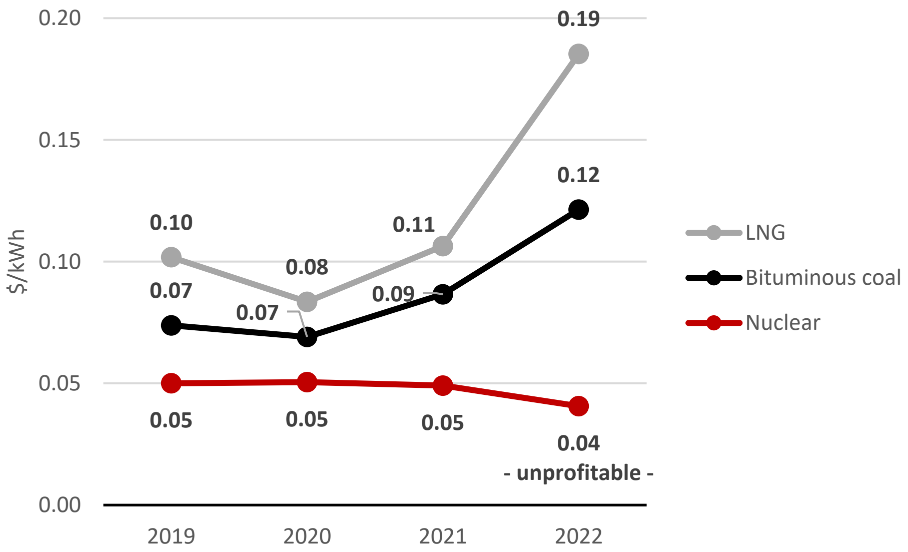
The estimates provided for nuclear reactors, bituminous coal and LNG fired power plants are their settlement unit prices. In South Korea, nuclear and fossil power plants are not paid at the wholesale price of electricity. Instead, they receive different settlement unit prices based on their respective costs (including both fixed and variable costs). These settlement unit prices are set monthly by the Generation Cost Assessment Committee after examination of cost data submitted by the power generation companies.

In South Korea, KEPCO is the single buyer in the electricity market. The lower the settlement unit prices are, the lower KEPCO's procurement costs are.

It is important to note here that the settlement unit price for nuclear power was decreased to $0.04/kWh in 2022. The motivation behind this decision was to help a financially weakened KEPCO to procure electricity as cheaply as possible.

This excessively low price made nuclear power unprofitable and resulted in economic losses for Korea Hydro & Nuclear Power, the country's sole operator of nuclear reactors [55]. Deteriorating the economic situation of Korea Hydro & Nuclear Power could ultimately lead to unacceptably sacrificing investments in nuclear safety.

Chart 19: South Korea Settlement Unit Prices of Nuclear, Bituminous Coal, and LNG 2019-2022



Note: In 2022, the settlement unit price for nuclear was set at $0.04/kWh which was too low. As a result, Korea Hydro & Nuclear Power suffered economic losses.

Source: Electric Power Statistics Information System, Electricity Market: Unit Cost by Fuel (accessed August 30, 2023).

Based on this track-record, and the fact that nuclear power emits a low quantity of GHG emissions, the South Korean government recognizes nuclear power as an effective option for decarbonization.

As a result, it is decided in the Basic Plan for Long-Term Electricity Supply and Demand to increase the share of nuclear power in electricity generation from 29.6% in 2022 to 32.4% in 2030, and 34.6% in 2036.

To achieve these targets nuclear power installed capacity should increase from 24.7 GW in 2022 to 28.9 GW in 2030, and 31.7 GW in 2036.

Increasing nuclear power installed capacity is planned to be realized by extending the lifespan of the country's oldest operational reactors and by commissioning five new reactors (7 GW) (table 2 on next page). To date, however, of the ten operational reactors which will reach the end of their operating license before 2030, only one (Kori-2) has applied for a lifespan extension, and only three reactors are currently under construction (Shin-Hanul-2, Saeul-3 & -4, each with a capacity of 1,400 MW). It may be noted that Kori-2's operating license expired on April 8, 2023, and its operation has consequently been suspended. This reactor may be restarted in June 2025 at the earliest[56]. Thus, the South Korean nuclear power industry will have plenty of work to do in the coming years to meet the country's nuclear power targets.

Table 2: South Korea Nuclear Reactors Lifespan Extensions by 2030 and New Constructions

Status	Name	Capacity (MW)	Retirement year	Note
Existing	Kori-2	650	2023	Application for lifespan extension
	Kori-3	950	2024	No application for lifespan extension
	Hanbit-1	950	2025	No application for lifespan extension
	Kori-4	950	2025	No application for lifespan extension
	Hanbit-2	950	2026	No application for lifespan extension
	Wolsong-2	700	2026	No application for lifespan extension
	Hanul-1	950	2027	No application for lifespan extension
	Wolsong-3	700	2027	No application for lifespan extension
	Hanul-2	950	2028	No application for lifespan extension
	Wolsong-4	700	2029	No application for lifespan extension
	10 reactors	**8,450**		
Status	Name	Capacity (MW)	Commissiong year	Note
New	Shin-Hanul-2	1,400	2023	Under construction
	Saeul-3	1,400	2024	Under construction
	Saeul-4	1,400	2025	Under construction
	Shin-Hanul-3	1,400	2032	Under preparation for construction
	Shin-Hanul-4	1,400	2033	Under preparation for construction
	5 reactors	**7,000**		

Sources: For lifespan extensions of existing reactors; Mycle Schneider Consulting Project, The World Nuclear Industry Status Report 2022 (October 2022). For new constructions; South Korea Ministry of Trade, Industry and Energy, Basic Plan for Long-Term Electricity Supply and Demand – 10th edition (January 2023) [in Korean].

- Legitimate safety concerns

If the technical and economic track-record of nuclear power in South Korea is apparently decent, the reputation of the industry suffers from legitimate safety concerns because of a series of issues, among which:

On February 9, 2012, the reactor Kori-1 suffered a loss of power due to human error during a test of the main generator[57]. Then, one of the two emergency diesel generators failed to start (the other one was undergoing maintenance). In addition, the connection to one of the two offsite auxiliary transformers failed to work as it had not been properly set up after maintenance (the other one was just entering maintenance). This caused a station blackout. Cooling was lost for 11 minutes. This significant incident was reported to the Nuclear Safety and Security Commission (i.e., South Korea's nuclear regulation authority) on March 12, more than one month later.

In September 2012, Korea Hydro & Nuclear Power was informed by a whistleblower about problems along its supply chain. Two months later, the company reported that its investigation had revealed that it had been supplied with falsely-certified non-safety-critical parts for five reactors [58]. Eight suppliers forged some 60 quality control certificates covering 7,682 components delivered between 2003 and 2012. The majority of the parts were installed at Hanbit-5- & -6, while the rest were used at Hanbit-3 & -4m and Hanul-3.

In May 2013, safety-related control cabling with falsified documentation was found to have been installed at three operational reactors: Shin-Kori-1 & -2, and Shin-Wolsong-1, and at three reactors which were then under construction: Saeul-1 & -2, and Shin-Wolsong-2[59].

Finally, according to a 2020 report by Korea Hydro & Nuclear Power, tritium was discovered in groundwater near the storage tanks for spent fuel rods at the Wolsong nuclear power plant[60]. In this report it was also indicated that the tritium amounts found in the water were as high as 13.2 times the safety standard. This radiation leakage caused public concern.

These safety issues have rightly eroded the trust of the South Korean population in nuclear power. Distrust in nuclear power is also reinforced by unsolved problems related to spent nuclear fuel and radioactive waste management.

In South Korea, spent fuel is temporarily stored on each nuclear power reactor site. There is neither a centralized interim storage facility nor permanent waste disposal facility. As spent fuel accumulates, temporary storage facilities approach saturation.

This is a key issue because residents living near nuclear power plants strongly oppose the extension of temporary storage facilities[61]. The reason is that they fear that these facilities would eventually become de facto permanent disposal facilities if a centralized interim storage facility or a permanent waste disposal facility is not developed. This is a real risk insofar as there is also strong resistance to these sensitive projects. Increasing nuclear power without finding a solution for spent fuel and radioactive waste management is an equation that is impossible to solve.

The South Korean government currently optimistically envisions that a centralized interim storage facility could be operational by 2035, and that a final repository could be operational by the mid-2050s[62]. Without concrete progress such as determining the locations of these facilities, this plan lacks credibility. This complicated situation casts a shadow over nuclear power future in South Korea.

2) Coal and gas power: high risk of carbon lock-in

Because of its unambitious targets for RE, and despite a questionable heavy reliance on nuclear power, South Korea still plans to significantly rely on coal and gas power in the medium-term. This strategy in favor of fossil fuels may be criticized on three grounds: energy security, economics, and environment.

South Korea's poverty in terms of fossil fuel resources is extreme. Close to 100% of the coal and gas used in the country's power plants are imported. This is a severe weakness in terms of energy security as it makes South Korea's power system vulnerable to uncontrollable overseas fossil fuel supply disruption risks.

Dependence on fossil fuel imports is also a source of fragility for the country's economy which suffers from volatile prices. As demonstrated by the recovery of the COVID-19 pandemic in the second half of 2021, and even more by the invasion of Ukraine by Russia since February 2022, fossil fuel prices are not only volatile they can also become prohibitively expensive (e.g., fuel costs of $0.09/kWh for bituminous coal and $0.16/kWh for LNG in 2022)[63].

Finally, from a decarbonization perspective, coal is the most polluting source of energy and there is a scientific consensus that it should be phased out as soon as possible. Instead, in the Basic Plan for Long-Term Electricity Supply and Demand, the targets for the share of coal power in the country's electricity generation mix are 19.7% by 2030 and 14.4% by 2036 (32.5 % in 2022).

In comparison, the targets for the share of gas power, that is less polluting but more expensive, are 22.9% by 2030 and 9.3% by 2036 (27.5% in 2022).

These targets are certainly controversial, so are the cofiring plans advanced by the South Korean government.

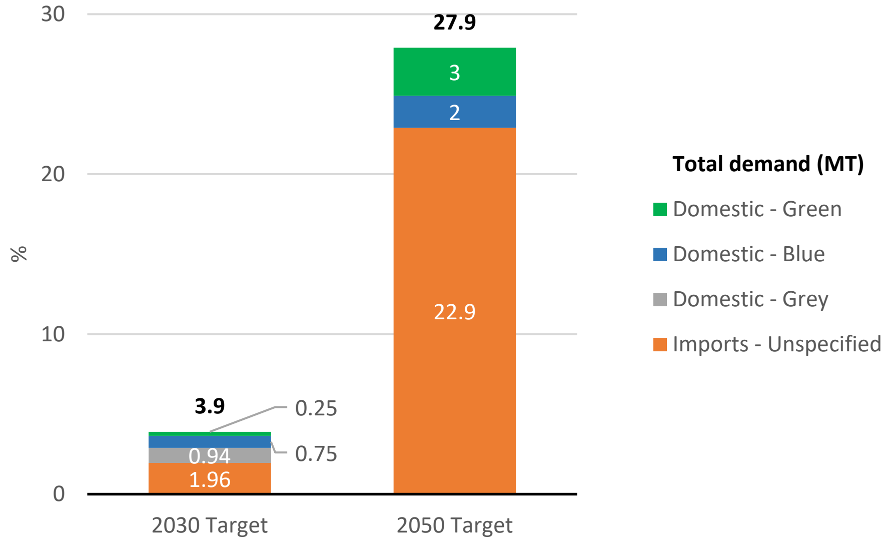
To reduce the GHG emissions from coal and gas power, the government plans to cofire coal with ammonia (20%) and gas with hydrogen (50%)[64]. Based on these cofiring ratios, and a projected growing number of power plants using these cofiring technologies, the combined share of ammonia & hydrogen is planned to reach 2.1% in the country's electricity generation mix by 2030, and 7.1% by 2036.

These types of cofiring power plants do not have solid track-records, either economically or environmentally. More specifically, in recent studies dedicated to Bangladesh and Vietnam, BloombergNEF found that cofiring coal with ammonia (25%) is currently approximately 15-60% more expensive than burning coal alone ($0.08-0.13/kWh), and that cofiring gas with hydrogen (50%) is twice more expensive than burning gas alone ($0.09-0.10/kWh) (for the cofiring estimates, the colors of ammonia and hydrogen are not specified)[65]. In addition, in another analysis dedicated to Japan, BloombergNEF also found that cofiring coal with green ammonia (20%) still emits 1.8 times more carbon dioxide than a CCGT only burning natural gas[66]. These poor performances are largely insufficient to contribute to the much-needed decarbonization of the power sector.

Should this doubtful cofiring strategy fail, it is likely that South Korea will rely more on coal and gas than currently planned. In other words, there is a real risk of significant carbon lock-in.

Another issue of this cofiring plan is that the colors of ammonia and hydrogen are unspecified. Based on the government's "Basic Plan for the Implementation of the Hydrogen Economy" (1st edition) published in November 2021, hydrogen to be consumed in South Korea will mainly be imported (the color is unspecified) (Chart 20 on next page). In 2030, domestic production of hydrogen will be grey (from natural gas), blue (from natural gas and using carbon capture and storage), and green (from RE electricity and using electrolysis). In 2050, domestic production of hydrogen will only be blue and green.

Chart 20: South Korea Hydrogen Supply 2030 & 2050 Targets



Source: South Korea Ministry of Trade, Industry and Energy, Basic Plan for the Implementation of the Hydrogen Economy – 1st edition (November 2021) [in Korean].

To support the uptake of ammonia and hydrogen power, two different auctions have started to be organized based on the type of hydrogen used for electricity generation: the general hydrogen auction (including grey hydrogen) and the clean hydrogen auction (including blue and green hydrogens).

The results of the first general hydrogen auction were announced in August 2023[67]. A total of 89 MW was awarded to fuel cell projects.

The clean hydrogen auction will be launched in 2024[68].

Rather than promoting cofiring of ammonia and hydrogen, pursuing further efforts in carbon pricing is likely to be more effective to reduce the GHG emissions of the power sector.

In 2015, South Korea became the first country in Northeast Asia to introduce a nationwide mandatory emissions trading system (ETS)[69]. Despite this pioneering effort, limited progress has been achieved in this framework. This is because emissions allowances are mostly allocated for free, and there has been an oversupply of allowances in the past one and a half year. As a result, the price of emissions allowances collapsed from nearly \$30 per ton of carbon dioxide equivalent (tCO_2-eq) at the beginning of February 2022 to below \$8/tCO_2-eq at the end of June 2023 (Chart 21 on next page). In comparison, the price of emissions allowances in the European Union ETS was \$94/tCO_2-eq at the end of June 2023, almost 12 times higher than in South Korea ETS.

Chart 21: South Korea ETS Allowance Price January 12, 2015-June 30, 2023

Source: International Carbon Action Partnership, Allowance Price Explorer – updated June 30, 2023 (accessed September 29, 2023).

More specifically, South Korea's ETS is currently in its third implementation phase (2021-2025). In this phase, 90% of emissions allowances for the power sector are freely allocated (i.e., only 10% are paid for in auctions)[70]. Free allowances aim at mitigating the risk of carbon leakage (i.e., relocation of businesses in other countries where environmental policies are less strict). On the downside, free allowances are an obstacle to reaching meaningful carbon prices.

Therefore, to maximize the efficiency of its ETS, South Korea needs to terminate free allocation of emissions allowances for the power sector and tighten the emissions cap to a level that would be compatible with a carbon neutral pathway.

Conclusion

Despite the unambitious plans of its government, South Korea does not have to remain a renewable energy laggard.

To go beyond the current government's renewable energy plans, the challenges of suboptimal natural conditions, high generating costs, subsidized retail electricity prices, and social opposition need to be overcome. For each of these challenges solutions exist. These include taking advantage of all deployment opportunities (e.g., rooftop solar photovoltaic, floating offshore wind…), taking into account renewable energy projected future cost decreases, reforming retail electricity prices, and building consensuses when advancing projects.

From a renewable energy policy perspective, South Korea is implementing various programs such as the renewable portfolio standard, renewable energy certificates, auctions, and small-scale solar photovoltaic feed-in tariff. However, to optimize their effectiveness more simplicity and continuity are required. For South Korean companies, it is of utmost importance that renewable energy progress happens rapidly as they are losing international competitiveness. Pioneering companies have well-understood this risk, and they have started to rise to the challenge by aiming for 100% renewable energy procurement.

Failing to achieve a high share of renewable energy in electricity generation results in problematic continuous reliance on nuclear and fossil power. Both are undesirable. Concerning nuclear power, there are legitimate safety concerns and unsolved problems related to spent nuclear fuel and radioactive waste management. Regarding fossil power, there is a risk of carbon lock-in because co-firing coal with ammonia and gas with hydrogen do not have solid track-records. Instead pursuing further efforts in carbon pricing is likely to be more effective to reduce greenhouse gas emissions.

Japan is currently confronted with the same issues in terms of energy policy and strategic approach.

Given the geographical proximity and striking similarities of South Korea and Japan, the two countries can share the experiences and technologies toward decarbonization in sustainable ways focusing more on renewable energy and energy efficiency.

Annex A: Renewable Energy Certificates

- A source of income for renewable energy generators

Generally, RE projects in South Korea have two sources of income: the sale of electricity in the wholesale power market and the sale of RECs.

The wholesale price of electricity is determined by the power plant with the highest marginal generation cost (typically a gas power plant) participating in the hourly power market.

The price of RECs is determined by the supply and demand balance in the REC market, including the "spot" and "contract" markets. While spot trading is held every first and third Friday of the month, contracts (i.e., freely negotiated long-term fixed-price contracts of 20 years) can be signed at any time[71]. In 2022, 76% of RECs were traded in the contact market[72].

RECs are associated with different weights (or multipliers) depending on technologies, site conditions/fuels/performances, and/or system sizes (see next section).

On the one hand, RE developers can issue RECs by multiplying the volume of RE electricity they generate by the corresponding weight, and sell them. For example, if a developer generates 1 MWh and the weight is 2, then the quantity of RECs is 2.

Therefore, RE developers can issue more RECs by generating electricity from RE technologies recognized with high values. However, their revenues depend on the prices at which RECs are sold (i.e., a RE developer may not necessarily earn more by selling more RECs).

Meanwhile, RE developers can use RECs for RPS requirement, regardless of the weight (i.e., 1 REC for 1 MWh).

On the other hand, corporate buyers can use purchased RECs after the weight is adjusted. For example, if a corporate buyer purchases 2 RECs which were issued by using a weight of 2, then the volume of RE electricity procured is 1 MWh. This ensures that actual electricity consumption and actual RE electricity generation are exactly matched.

- A way to promote various technologies

To reflect the facts that RE technologies have different costs, GHG emissions reduction potentials, social acceptance levels, and technical maturities, as well as to ensure that a variety of complementary RE technologies are deployed, RECs are associated with different weights which are included in the calculation of RE generators' income.

A low certificate weight (i.e., 0.5 or below) is granted to technologies which are economically competitive, or have a low potential for GHG emissions reduction, or face social acceptance issues, or are technically mature. For instance, renewable waste (0.25) and solar PV in forest areas (0.5).

A high certificate weight (i.e., 1.5 or above) is granted to technologies which costs are rather high, or have a high potential for GHG emissions reduction, or are socially well-accepted, or are innovative. For examples, small-scale (<100 kW) floating solar PV (1.6) and fuel cell using by-product hydrogen with a good energy efficiency >65% (2.2).

South Korea REC Weights by Technology, as of January 2023

Technology	Site condition/fuel/performance	System size	Certificate weight
Bioenergy & renewable waste	Unused forest biomass	-	2
	Co-firing of unused forest biomass	-	1.5
	Biogas	-	1
	Wood pellet/chip	-	0.5
	Landfill gas	-	0.5
	Black liquor	-	0.25
	Bio-solid recovered fuels	-	0.25
	Renewable waste (e.g., domestic waste)	-	0.25
	Other bioenergy (i.e., livestock manure solid fuel, sewage sludge, solidified fuel, bio heavy oil)	-	1
Fuel cell	-	-	1.9
	Using by-product hydrogen	-	+0.1
	With energy efficiency >65%	-	+0.2
Geothermal	-	-	1 to 2.5
Hydro	-	-	1.5
Marine	Ocean current	-	2
	Tidal without seawall – fixed	-	1.75
	Tidal without seawall – floating	-	1 to 2.5
	Tidal with seawall	-	1
Solar PV	Ground-mounted	<100 kW	1.2
		100 kW-3 MW	1
		>3 MW	0.8
	Rooftop	≤3 MW	1.5
		>3 MW	1
	Floating	<100 kW	1.6
		100 kW-3 MW	1.4
		>3 MW	1.2
	Forest	-	0.5
	Self-consumption	-	1
Wind	Onshore wind	-	1.2
	Offshore wind coastal (i.e., inside tidal flats and seawalls)	-	2.0 (basic weight)
	Offshore wind maritime	-	2.5 (basic weight)
	For projects which connection distance >5 km and water depth >20 m additional support is provided	-	+0.4 (composite) for each additional 5 km and 5m

Source: BloombergNEF, South Korea Market Outlook 2023 H1: Pivot to Nuclear (February 2023) [subscription required].

As for offshore wind, the certificate weight needs to be calculated considering connection distance and water depth. The following equation applies:

Certificate weight = connection distance composite weight + water depth composite weight – basic weight

The connection distance composite weight is calculated using four different equations by step of 5 km of distance from ≤5 km to >15 km.

South Korea Offshore Wind REC Connection Distance Composite Weight Equations

Connection distance	Equation
≤5 km	Basic weight
>5 km-10 km	[5 × basic weight + (distance - 5) × (basic weight + 0.4)] / distance
>10 km-15 km	[5 × basic weight + 5 × (basic weight + 0.4) + (distance - 10) × (basic weight +0.8)] / distance
>15 km	[5 × basic weight + 5 × (basic weight + 0.4) + 5 × (basic weight + 0.8) + (distance - 15) × (basic weight +1.2)] / distance

Source: Jongmin Lee and George Xydis [Clean Technologies and Environmental Policy], Floating Offshore Wind Projects Development in South Korea without Government Subsidies (June 2023).

The water depth composite weight is calculated using four different equations by step of 5 m of depth from ≤20 m to >30 m.

South Korea Offshore Wind REC Water Depth Composite Weight Equations

Water depth	Equation
≤20 m	Basic weight
>20 m-25 m	[5 × basic weight + (depth - 20) × (basic weight + 0.4)] / (depth - 15)
>25 m-30 m	[5 × basic weight + 5 × (basic weight + 0.4) + (depth - 25) × (basic weight +0.8)] / (depth - 15)
>30 m	[5 × basic weight + 5 × (basic weight + 0.4) + 5 × (basic weight + 0.8) + (depth - 30) × (basic weight +1.2)] / (depth - 15)

Source: Jongmin Lee and George Xydis [Clean Technologies and Environmental Policy], Floating Offshore Wind Projects Development in South Korea without Government Subsidies (June 2023).

To ensure a good understanding of this rather sophisticated approach, a concrete example is provided assuming a fictious offshore wind maritime project with a connection distance of 15 km and a water depth of 30 m.

In this case:

- The basic weight is: 2.5,
- The connection distance composite weight is: 2.9, obtained thanks to the following calculation; [5 × 2.5 + 5 × (2.5 + 0.4) + (15 - 10) × (2.5 +0.8)] / 15, and
- The water depth composite weight is: 2.9, obtained thanks to the following calculation; [5 × 2.5 + 5 × (2.5 + 0.4) + (30 - 25) × (2.5 +0.8)] / (30 - 15).

As a result, the certificate weight is: 3.3, obtained thanks to the following calculation; 2.9 + 2.9 - 2.5.

Annex B: Renewable Energy Procurement Options[73]

- Green tariffs

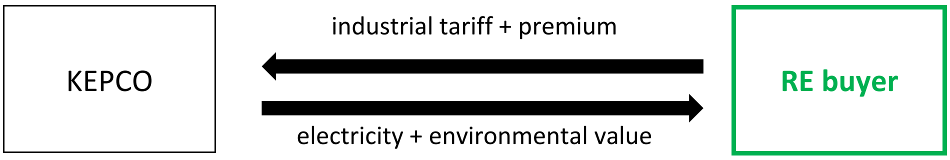
Greens tariffs are determined by auctions regularly organized (i.e., from the second half of 2023 three times a year, instead of twice a year previously) in which RE buyers express the additional amount (i.e., premium) they are willing to pay on top of KEPCO's industrial tariff ($0.11/kWh, including grid and supplier fees) to procure RE electricity.

In these auctions, the lowest bidding limit is $0.01/kWh[74]. In the latest auction round for the first half of 2023, the premium RE buyers should pay was settled at $0.01/kWh.

The premium of the green tariffs is transferred from KEPCO to the Korean Energy Agency, and it is used to reinvest in RE[75].

The major issue of green tariffs is that KEPCO does not disclose the exact source of the electricity. As a result, additionality benefits are unclear.

Green Tariffs – Simplified Illustration from RE Buyers' Perspective



- RECs

A REC is a tradable commodity that is created by generating 1 MWh of RE electricity.

The price of RECs is determined by the supply and demand balance in the REC market, including the "spot" and "contract" markets. Spot trading is held twice a month. Long-term fixed-price contracts can be signed at any time.

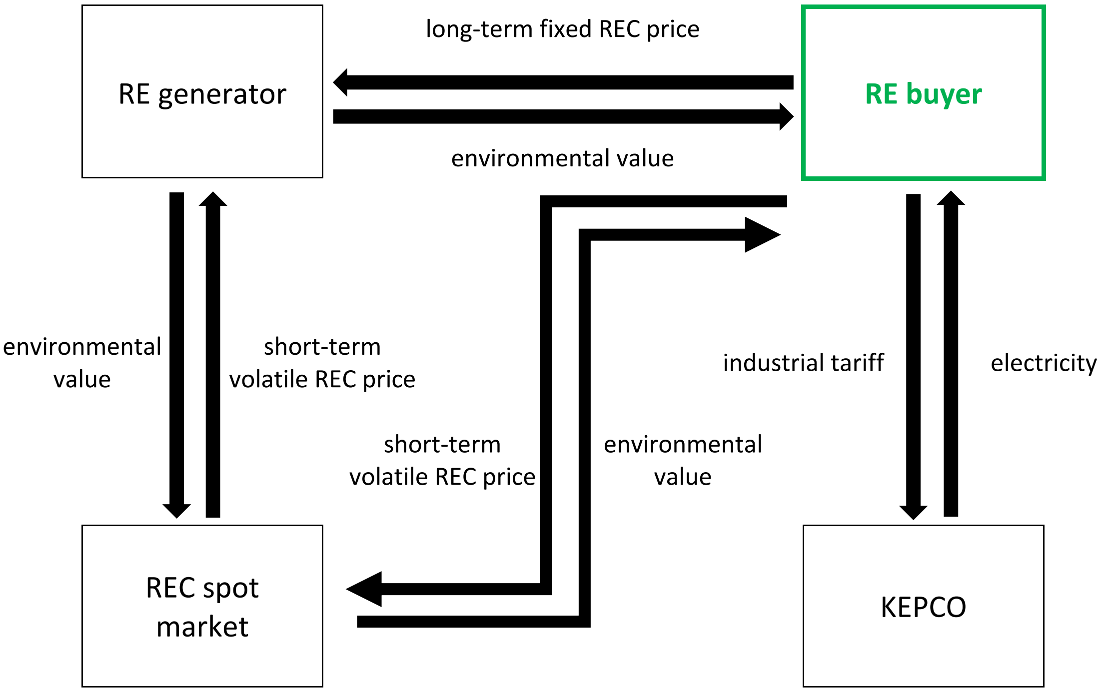
Just like the premium of the green tariffs, the prices of RECs come on top of KEPCO's industrial tariff. However, in the case of RECs, the electricity and environmental value are procured separately.

The first long-term fixed-price contract was signed in April 2022 between LG Chem and Korea South-East Power for RECs generated from a 10 MW solar PV power plant.

In May 2023, long-term REC contracts between unidentified organizations were signed at $0.04-0.05/kWh, lower than the spot REC market price of $0.06/kWh (spot prices are intrinsically volatile).

Additionality on using RECs is considered to be higher than with green tariffs because RE buyers can confirm the additionality by the values in the REC.

RECs – Simplified Illustration from RE Buyers' Perspective



- Self-generation

Self-generation consists for a RE buyer to invest in RE power generating assets to meet its own electricity needs. The acquisition of electricity and its environmental value are immediate. This approach has high additionality.

RE power generating assets may be installed onsite or offsite. If they are installed offsite, KEPCO's grid fee is incurred.

In South Korea, the cost of onsite self-generation for solar PV is estimated between $0.11/kWh and $0.14/kWh, which is low among RE procurement options.

On the downside, self-generation requires the end-user to manage the lifecycle of the facility. This may be a hurdle as most South Korean companies have no experience in the energy business. Or it is possible to outsource the operation to energy service providers.

An example of self-generation project by a South Korean company is that of Samsung Electronics which has installed rooftop solar PV facilities over parking lots in four of its chip production plants.

Samsung Electronics Self-Generation Rooftop Solar PV Project at Giheung Chip Factory

Source: Samsung, How We'Re Using the Sun to Fight Climate Change (accessed August 28, 2023).

- Corporate PPAs

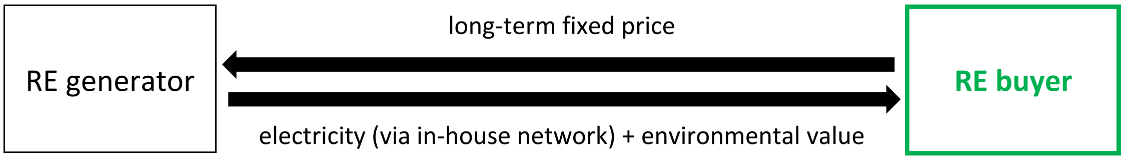
There are two types of corporate PPAs in South Korea: direct PPAs and third-party PPAs. In the case of direct PPAs, RE buyers can sign purchase agreements directly with RE providers (i.e., RE generators or RE suppliers). In the case of third-party PPAs, purchase agreements between RE buyers and RE generators are brokered by KEPCO.

There is another important difference between direct PPAs and third-party PPAs. In the framework of direct PPAs, electricity in excess of buyers' demand can be traded on the market. In the framework of third-party PPAs, buyers are required to purchase the entire volume of the electricity the generators produce, and the electricity in excess of buyers' demand cannot be traded on the market.

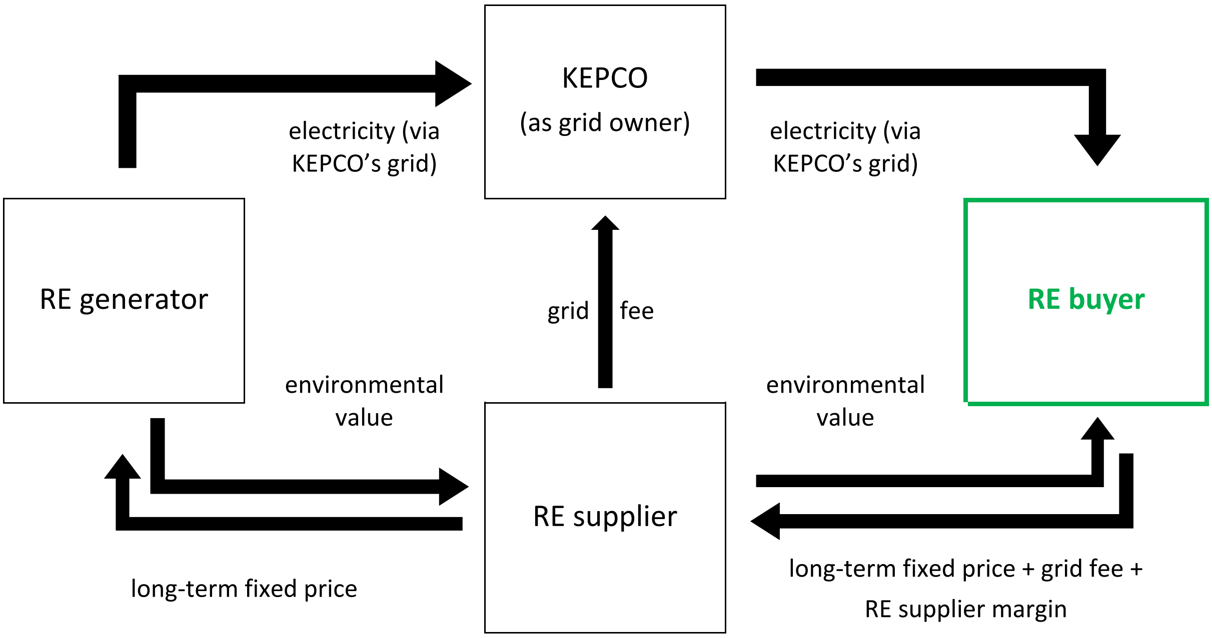
Direct PPAs can be arranged in two ways: onsite and offsite. Onsite direct PPAs differ from self-generation in the way that the installation, maintenance, and management of the facility is overseen by the RE generator. As an example of such a project, in September 2022, LG Electronics and GS EPS signed a direct PPA related to a 5 MW onsite solar PV project for a 20-year period.

Both direct and third-party PPAs offer high additionality, but they suffer from complexity and relatively high costs (compared to other RE procurement options): in the range of \$0.15-0.18/kWh. However, considering the LCOE for solar PV is \$0.10/kWh in South Korea, including the grid fee and the margin for the RE supplier, this price range appears reasonable.

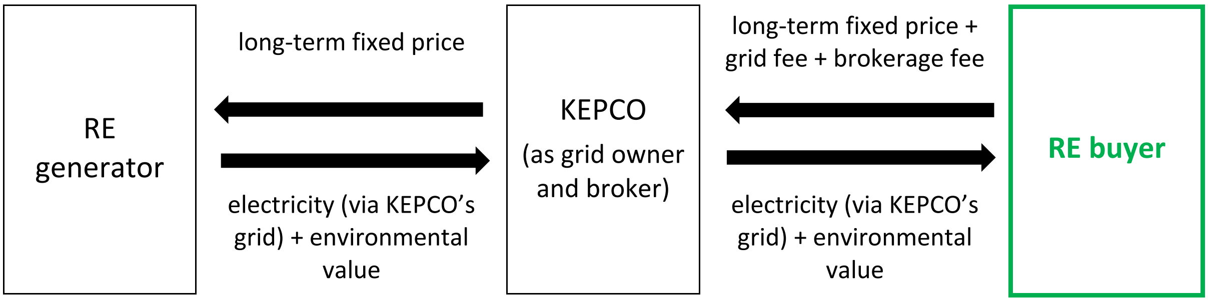
Onsite Direct PPAs Simplified Illustration from RE Buyers' Perspective



Offsite Direct PPAs Simplified Illustration from RE Buyers' Perspective



Third-Party PPAs Simplified Illustration from RE Buyers' Perspective



List of Abbreviations

CCGT: combined-cycle gas turbine

ETS: emissions trading system

FiT: feed-in tariff

FY: fiscal year

GHG: greenhouse gas

GW: gigawatt

GWh: gigawatt-hour

HVDC: high-voltage direct current

IEA: International Energy Agency

IGCC: integrated gasification combined cycle

KEPCO: Korea Electric Power Corporation

km: kilometer

kW: kilowatt

kWh: kilowatt-hour

LCOE: levelized cost of electricity

LNG: liquefied natural gas

m: meter

MT: million tons

MW: megawatt

MWh: megawatt-hour

NDC: Nationally Determined Contribution

O&M: operation and maintenance

OECD: Organization for Economic Co-operation and Development

PPA: power purchase agreement

RE: renewable energy

REC: renewable energy certificate

RPS: renewable portfolio standard

Solar PV: solar photovoltaic

tCO_2-eq: ton of carbon dioxide equivalent

TWh: terawatt-hour

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South Korea
Low Renewable Energy Ambitions Result in High Nuclear and Fossil Power Dependencies

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