CLIMATE CHANGE
36/2021

The Korea Emissions Trading System and electricity market

Influence of market structures and market regulation on the carbon market

Case Study Report

German Environment Agency

Umwelt Bundesamt

CLIMATE CHANGE 36/2021

Ressortforschungsplan of the Federal Ministry for the
Enviroment, Nature Conservation and Nuclear Safety

Project No. (FKZ) 3718 42 002 0

Report No. FB000418/ZW,3,ENG

The Korea Emissions Trading System and electricity market

Influence of market structures and market regulation on the carbon market

Case study report

by

Ernst Kuneman, William Acworth, Tobias Bernstein
adelphi, Berlin

Anatole Boute
Chinese University Hong Kong, Hong Kong

On behalf of the German Environment Agency

Imprint

Publisher
Umweltbundesamt
Wörlitzer Platz 1
06844 Dessau-Roßlau
Tel: +49 340-2103-0
Fax: +49 340-2103-2285
buergerservice@uba.de
Internet: www.umweltbundesamt.de

/umweltbundesamt.de
/umweltbundesamt

Report performed by:
adelphi research gemeinnützige GmbH
Alt-Moabit 91
10559 Berlin
Germany
+49 (030) 8900068-0
office@adelphi.de
www.adelphi.de

Report completed in:
August 2020

Edited by:
Section V 3.3 Economic Aspects of Emissions Trading, Monitoring, Evaluation
Claudia Gibis

Publication as pdf:
http://www.umweltbundesamt.de/publikationen

ISSN 1862-4804

Dessau-Roßlau, May 2021

Acknowledgements

The authors express their gratitude to Dr. Yong-Gun Kim (Korea Environment Institute) and Prof. Seung Jick Yoo (Sookmyung Women's University) for their review of an earlier draft version which greatly benefitted this report.

Abstract

This report analyses the interactions between the Korea ETS (K-ETS) and the electricity sector. We 1) analyse the carbon price signal along four criteria: volatility, reflection of marginal abatement costs, predictability, and environmental effectiveness; and 2) assess interactions of the allowance price with the structure of the electricity sector and market regulations across electricity consumption, production, and investment. Since its launch in 2015, the K-ETS allowance price has featured a relatively stable upward development. Periodic volatility has occurred around the end of compliance periods, policy announcements and due to external shocks such as the COVID-19 pandemic. Where Phase 3 reforms would see improved price discovery in the system, a reduction in demand resulting from reduced economic activity as Korea and the rest of the globe tackled the pandemic presents a new risk of oversupply in the short term. Despite high allowance prices having continued well into 2020, we find that the K-ETS has had negligible impact on electricity sector abatement due to lack of cost pass-through in wholesale electricity prices, subsidised allowance purchases for electricity producers and low net costs for large consumers. Regulatory alignment is set to improve with ongoing discussions on further electricity market reforms next to the introduction of an environmental dispatch mechanism, which could see (part of) allowance costs reflected in generators' operational costs. Recent reforms to the retail tariff to include environmental costs will support cost recovery and may pave the way for full carbon cost pass through in the coming years.

Kurzbeschreibung

Dieser Bericht analysiert die Wechselwirkungen zwischen dem südkoreanischen Emissionshandelssystem (K-ETS) und dem Stromsektor. Wir analysieren erstens das CO_2-Preissignal anhand von vier Kriterien: Preisschwankungen, Widerspiegelung der Grenzvermeidungskosten von CO_2-Emissionen, Vorhersehbarkeit und Umweltwirksamkeit. Zweitens bewerten wir die Wechselwirkungen des Zertifikatspreises mit der Struktur des Stromsektors sowie mit Marktregelungen hinsichtlich Stromverbrauch, -produktion und Investitionen. Seit seiner Einführung im Jahr 2015 ist der Zertifikatspreis des K-ETS relativ kontinuierlich gestiegen. Phasenweise Preisschwankungen traten am Ende der Erfüllungszeiträume, als Folge politischer Ankündigungen und aufgrund externer Einflüsse wie der COVID-19-Pandemie auf. Während die Reformen der Phase 3 des K-ETS zu einer verbesserten Preisfindung im System führen würden, stellt ein anhaltender Nachfragerückgang nach Zertifikaten aufgrund einer verminderten Wirtschaftstätigkeit im Zuge der Bekämpfung von COVID-19 in Südkorea und auf der ganzen Welt ein neues Risiko eines lang anhaltenden Überangebots an Zertifikaten dar. Trotz der hohen Zertifikatspreise bis weit in das Jahr 2020 hinein, stellen wir fest, dass das K-ETS keinen wesentlichen Einfluss auf die Emissionsminderungen im südkoreanischen Stromsektor hatte. Das hängt damit zusammen, dass die Kosten der Zertifikatspreise nur unzureichend auf die Großhandelsstrompreise umgelegt wurden, die Zertifikate, die die Stromerzeuger gekauft haben, subventioniert waren und die Nettostromkosten für Großverbraucher niedrig waren. Die Angleichung der Regelungen des ETS mit denen des Stromsektors wird mit den laufenden Diskussionen über weitere Reformen des Strommarktes und die Einführung eines ökologischen Dispatch-Mechanismus, mit dem sich die Kosten für die Zertifikate (teilweise) in den Betriebskosten der Stromerzeuger widerspiegeln könnten, weiter voranschreiten. Jüngste Reformen der Stromtarife zur Einbeziehung von umweltbezogenen Kosten werden die Kostendeckung unterstützen und könnten den Weg für eine vollständige Weitergabe des CO_2-Preises in den kommenden Jahren ebnen.

Table of Contents

List of tables

List of figures

List of abbreviations

BM	Benchmarking
BPLE	Basic Plan for Long-term Electricity Supply and Demand
CAPEX	Capital Expenditure
CBP	Cost-based Pool
CHP	Combined heat and power
CO_2	Carbon dioxide
CP	Capacity payment
DH	District heating
DSM	Demand-side management
EPSIS	Electric Power Statistics Information System
ETS	Emissions trading system
EUR	Euros
GCAC	Generation Cost Assessment Committee
GENCOs	Generation Companies
GIR	The Greenhouse Gas Inventory & Research Center of Korea
GP	Grandparenting
GW	Gigawatt
ICAP	International Carbon Action Partnership
IPPs	Independent power producers
IRR	Internal rate of return
KAU	Korean Allowance Unites
KCUs	Korean Credit Units
KEPCO	Korea Electric Power Corporation
K-ETS	Korea Emissions Trading System
KOCs	Korean Offset Credits
KPX	Korea Power Exchange
KRW	Korean Won
KPX	Korea Power Exchange
KRX	Korea Exchange
kWh	Kilowatt hours
LCOE	Levelized cost of electricity
LNG	Liquified natural gas
MAC	Marginal abatement costs

MoE	Ministry of Environment
MoEF	Ministry of Economy and Finance
MOTIE	Ministry of Trade, Industry, and Energy
MW	Megawatts
MWh	Megawatt hours
NOx	Nitrous oxides
NPV	Net present value
OPEX	Operating expenditure
OTC	Over-the-Counter
PBP	Price-based Pool
PPAs	Power purchase agreements
PSS	Price setting schedule
PV	Photovoltaic
RE	Renewable energy
ROK	Republic of Korea
RPS	Renewable portfolio standard
SMP	System Marginal Price
SOx	Sulfur oxides
TMS	Target Management System
TWh	Terawatt hours
UNFCCC	United Nations Framework Convention on Climate Change
VRE	Variable renewable energy

Summary and Conclusions

This report analyses the interactions between the Korean Emissions Trading System (K-ETS) and the electricity market along two main questions: 1) how K-ETS design features impact the quality of the allowance price signal; and 2) how market design features and additional regulations in Korea's electricity sector impact abatement opportunities induced by the allowance price.

Impacts of carbon market design and market regulations on the quality of the price signal

Since its launch in 2015, the K-ETS has evolved into one of the country's principle mechanisms for achieving its emission reduction target. Over the years, it has delivered a gradually increasing allowance price, reaching a peak toward the end of 2019 where it remained until May 2020. After this point, prices started to drop in line with reduced 2019 emissions and as a result of a decline in economic activity associated with COVID-19 containment measures. Phase 3 (2021–2025) reforms adopted in Q3 of 2020 may strengthen Korean Allowance Units (KAUs) in their recovery from a bearish year. The prospects for increased ambition going forward, following a shifting political landscape and the introduction of a net zero emissions target will likely support the allowance price in the long run. This will, however, be contingent on policy alignment and the role of the K-ETS in the broader policy mix.

- **Volatility**: Overall stable price development in the K-ETS has been interrupted by recurrent periods of increased short-run volatility reflected by temporary price peaks. Until May 2020, these were partly driven by expectations of future net shortage, which combined with design features such as high free allocation shares, a relatively closed market, a high share of over-the-counter (OTC) transactions and compliance-focussed trades, affected market liquidity. With the reversal of market dynamics in Q2 of 2020, volatility has increased, while low market liquidity remains a key challenge underlying price development. The introduction of third-party participation and higher auctioning shares in Phase 3 could considerably improve trade activity and price discovery going forward. Work is also underway to facilitate derivative trade.

- **Price reflection of marginal abatement cost (MAC):** Tackling low liquidity levels has been of concern to market authorities. Intra-phase policy reforms have aimed at stabilizing the market, often targeting rules on flexibility provisions. While such measures temporarily reassured market concerns over future scarcity, frequent changes may also have contributed to low market engagement. An increased risk premium on trading was reflected by a preference for covered entities to use banking and borrowing to meet their surrender obligations, rather than engage in market transactions, since 2019 addressed through rules that tie banking and borrowing limits to an entity's trade activity. Where the electricity sector is the largest covered sector and net-buyer in the K-ETS, electricity market regulations have further had a large impact on the K-ETS and are likely to have resulted in market distortions. Conventional power producers have received compensation for net allowance costs through a separate mechanism in Phase 2, which distorted the incentive to trade allowances in line with their marginal abatement costs, shifting the burden of abatement to costlier options in industry. In the opposite direction, the effect of companion policies in the power sector—mainly fine dust regulations and renewable energy—started to materialise in 2020 through lowered emissions, in turn contributing to a growing allowance surplus and decreasing KAU prices.

- **Predictability:** There are mixed signals on the long-term direction of the price signal under the K-ETS. One the one hand, short-term predictability is hampered by the release of the exact cap trajectories and free allocation criteria only shortly prior to the phases to which they apply, the implementation of interventions for market stability largely being through discretionary measures, the uncertain effects of companion policies, and a shifting political landscape in favour of ambitious climate policy where most details for the ETS are yet to be fleshed out. However, the medium-term picture significantly improved with the release of the Revised GHG roadmap in 2018, which set long-term emission reduction targets per sector and is set to improve further in Phase 3 (and 4) as a result of stronger price discovery and the potential introduction of a futures market.
- **Environmental effectiveness*:*** The environmental effectiveness of an ETS equals the amount of emissions abated, which in Korea has been ensured through the integrity of the cap and strict rules surrounding the use and eligibility criteria of additional sources of supply, namely domestic and international offsets.

Impact of electricity market structure and regulations on the potential for abatement under the ETS

The K-ETS has had a negligible impact on the electricity sector in Phases 1 and 2, as wholesale electricity prices have not reflected the allowance price, and conventional power producers have been compensated for net allowance costs through a mechanism that operates outside of electricity price formation. Some downstream abatement is, at least in theory, triggered through the inclusion of large electricity consumers under the K-ETS, although this effect has likely been limited by high shares of free allocation. Recently proposed electricity market reforms would ensure the ETS and electricity sector are better aligned. An environmental dispatch mechanism is scheduled to be introduced during 2022-2024, while discussions in parallel envisage further price liberalisation as part of the creation of a price-based pool market. Both options will enable net allowance costs to be reflected in wholesale electricity, where a price-based pool may potentially facilitate full carbon cost pass-through from 2025 onwards.

- **Capacity mix:** Korea's power mix is dominated by gas and coal, which have a roughly equal share and together account for close to two-thirds of total installed capacity. In terms of electricity generation, coal-fired power plants dominate other energy sources, accounting for 40% of total generation in 2019. Variable renewable energy sources have grown exponentially in the last decade and made up 6% of total generation in 2019. In this context, there is high latent potential for the carbon price to incentivise fuel switching and further spur renewable energy growth.
- **Age of coal fleet:** Korea has a relatively efficient coal fleet with an average age of 16 years. Coal plants are subject to emissions standards, fine dust regulations, a phase down plan with earmarked decommissioning and coal-to-gas retrofits, and a lifecycle limit of 30 years. The lifecycle cap, combined with capacity payments, mitigate the economic risk of stranded assets but also limit the role the carbon price may have in incentivising early decommissioning.

- **Companion policies:** The K-ETS operates alongside a range of energy policy instruments, such as capacity payments, renewable portfolio standards, emission performance standards, fuel taxes, phase down trajectories, and technology targets. Except for the phase down of nuclear, these are all—albeit to varying extent—aimed at decarbonising Korea's electricity generation mix. With more than 60GW of renewable capacity planned to be added to the grid towards 2034 under current policies, next to increasing shares of gas-fired capacity set to replace coal, allowance demand from the power sector is likely to decrease in the years ahead. Stricter obligations under the renewable portfolio standard (RPS) scheme put forward in the Korean Green New Deal, and the prospect of further revisions in line with a net neutrality pathway would result in larger shares of renewable energy sooner, exerting a downward effect on ETS prices proportional to reduced allowance demand. Increasing direct taxes on coal consumption is another mechanism the Republic of Korea (ROK) is employing in tandem with environmental dispatch to promote a switch to liquefied natural gas (LNG). In this dynamic policy environment, aligning the K-ETS with the broader policy mix will be essential for it to deliver a credible price signal that can guide dispatch and investment decisions. Clear and transparent market stability measures can ensure the K-ETS remains relevant given adjustments in other policy areas. As such, the role of the Allocation Committee and the rules that dictate when it can engage in the market could benefit from periodic review.

- **Pass-through of carbon costs to wholesale electricity prices:** In Phases 1 and 2 of the K-ETS, the regulated wholesale price did not reflect allowance costs, blocking the potential for clean dispatch while additionally, compensation for net allowance costs in effect preserved the internal rate of return on carbon-intensive generation assets. Under the proposal for ***environmental dispatch***, net allowance costs would be reflected in the system marginal price. The opportunity for fuel switching under this mechanism will depend on an accelerated phase-out of free allocation to the power sector. The proposed environmental dispatch mechanism can also support renewable energy producers through higher wholesale electricity prices, so long as generators at the margin face allowance costs.

- Looking further ahead, a full transition towards a ***price-based pool*** from 2025 would bring the opportunity to fully pass on carbon costs in wholesale electricity prices, thereby supporting low-carbon generation sources across the capacity mix. and triggering the ROK's significant fuel switching potential. Increasing exposure to CO_2 costs will also incentivise electricity producers to trade permits in line with their MAC, lower allowance demand through emission reductions, and decrease compliance costs for other sectors covered by the K-ETS. Targeted free allocation in a full pass-through scenario can help offset conventional producers' diminishing returns and smoothen the transition process. When accompanied with intraday price signals and the introduction of ancillary service markets, the role of the carbon price could be broadened to incentivising retrofit investments that increase plant flexibility, ensuring coal units produce less and when it matters most.

- **Pass-through of carbon costs to retail electricity prices:** The potential for carbon cost pass-through in Korea is, however, closely bound to electricity retail price reform and entails a political discussion on who should bear the costs of electricity sector abatement under the

K-ETS. The Korean Electric Power Corporation (KEPCO), the single buyer, faces increasing costs owing to higher system marginal price (SMP) rates it must pay generators but cannot fully recover through progressive retail rates. Passed-through allowance costs would add an extra cost burden for KEPCO which in Phases 1 and 2 of the K-ETS have been assumed by the Korean Power Exchange (KPX) through the cost compensation mechanism. Recent reforms to the retail tariff to separately bill climate costs will likely support cost recovery and may pave the way for full carbon cost pass through in the coming years. The gradual introduction of cost-reflective electricity dispatch and retail rates over time would require indirect emissions coverage to be phased out accordingly. In a scenario where 100% of allowance costs are passed through, cost-reflective retail prices can furthermore be coupled with a rebate scheme from ETS revenues, preserving the incentive for demand-side responses while keeping costs down for low-income groups or vulnerable industries.

With major reforms to both the K-ETS and the electricity sector in the pipeline, the next years will be indicative of the potential for accelerating emission reductions through the ETS. This will not just be crucial to Korea's decarbonisation pathway but could set an example for countries considering introducing carbon pricing policies to advance decarbonisation in regulated electricity sectors.

Zusammenfassung und Schlussfolgerungen

Dieser Bericht analysiert die Interaktionen zwischen dem südkoreanischen Emissionshandelssystem (Korean Emissions Trading System – K-ETS) und dem Strommarkt entlang zweier Hauptfragen: 1) wie sich die Eigenschaften des K-ETS auf die Qualität des Preissignals für Emissionszertifikate auswirken; und 2) wie sich die Eigenschaften des Strommarktes und zusätzliche Regelungen im koreanischen Stromsektor auf Möglichkeiten zur Emissionsminderung auswirken, die vom Zertifikatspreis ausgelöst werden.

Auswirkungen der Ausgestaltung des Kohlenstoffmarktes und der Regelungen im Strommarkt auf die Qualität des CO_2-Preissignals

Seit seiner Einführung im Jahr 2015 hat sich das K-ETS zu einem der wichtigsten Instrumente Südkoreas zur Erreichung seines Emissionsminderungsziels entwickelt. Im Laufe der Jahre ist der Preis für die Zertifikate schrittweise gestiegen und erreichte gegen Ende 2019 einen Höchststand, der bis Mai 2020 anhielt. In den Folgemonaten begannen die Preise als Resultat zurückgehender Emissionen zu sinken, was unter anderem auf einen Rückgang der wirtschaftlichen Aktivitäten im Zusammenhang mit den COVID-19-Einschränkungen zurückzuführen ist. Die im dritten Quartal 2020 verabschiedeten Reformen der Phase 3 des K-ETS (2021-2025) könnten den Preis der südkoreanischen Emissionszertifikate (*Korean Allowance Units* – KAUs) weiter steigen lassen und somit zur Erholung von negativen Marktentwicklungen führen. Die Aussichten auf zukünftige Ambitionssteigerungen in der Klimapolitik infolge einer sich verändernden politischen Landschaft und der Einführung eines Netto-Null-Emissionsziels werden das Niveau der Zertifikatspreise langfristig wahrscheinlich stärken. Dies wird jedoch auch von der politischen Ausrichtung und der Rolle des K-ETS im Policy-Mix abhängen.

- **Preisschwankungen:** Die insgesamt stabile Preisentwicklung im K-ETS wurde von wiederkehrenden Phasen erhöhter und zugleich kurzfristiger Preisschwankungen unterbrochen, die sich in temporären Preisspitzen widergespiegelt haben. Bis Mai 2020 waren diese zum Teil durch die Erwartung einer zukünftigen Knappheit von Emissionszertifikaten getrieben. Das beeinträchtigte zusammen mit bestimmten Eigenschaften des K-ETS, wie einem hohen Anteil an kostenlos zugeteilten Zertifikaten, einem relativ geschlossenen Markt, einem hohen Anteil an außerbörslichen (*over-the-counter* –OTC) Transaktionen und einem auf die Erfüllungszeiträume fokussierten Zertifikathandel, die Marktliquidität. Mit der Umkehrung der Marktdynamik im 2. Quartal 2020 haben Preisschwankungen zugenommen, während gleichzeitig die geringe Marktliquidität eine zentrale Herausforderung für die Preisentwicklung bleibt. Die Öffnung des Emissionshandels für die Beteiligung Dritter und höhere Versteigerungsanteile bei der Zuteilung der Zertifikate in Phase 3 des K-ETS könnten die Handelsaktivität und Preisfindung in Zukunft erheblich verbessern. Zudem ist eine Erleichterung des Handels mit Derivaten geplant.

- **Widerspiegelung der Grenzvermeidungskosten von CO_2-Emissionen im Preis:** Die Verbesserung der Marktliquidität ist ein Anliegen der Marktaufsichtsbehörden gewesen. Politische Reformen innerhalb der einzelnen Phasen des K-ETS haben daher beabsichtigt, den Markt zu stabilisieren und sich dabei oft auf die Einführung und Nutzung von Flexibilitätsmechanismen bezogen. Während solche Maßnahmen die Bedenken des Marktes hinsichtlich zukünftiger Knappheit von Zertifikaten vorübergehend beruhigten, könnten die häufigen Eingriffe und Änderungen auch zu den geringen Handelsaktivitäten innerhalb des Marktes beigetragen haben. Die Erwartung, dass die Teilnahme am Handel mit Zertifikaten mit einem erhöhten Risiko behaftet ist, spiegelte sich darin wider, dass die betroffenen Unternehmen lieber auf Flexibilitätsmechanismen wie Banking (die Übertragung von Zertifikaten auf einen späteren Zeitraum) und Borrowing (Nutzung von Zertifikaten aus späteren Zeiträumen) zurückgegriffen haben, um ihren Erfüllungsverpflichtungen nachzukommen, als sich an Transaktionen auf dem Emissionshandelsmarkt zu beteiligen. Dem wurde seit 2019 damit begegnet, dass Grenzwerte für erlaubtes Banking und Borrowing erlassen wurden, welche an die Handelsaktivität eines Unternehmens gekoppelt sind. Da der Stromsektor der größte vom K-ETS abgedeckte Sektor und Nettokäufer von Zertifikaten ist, haben die Regulierungen des Strommarktes einen weiteren großen Einfluss auf das K-ETS ausgeübt und vermutlich zu Marktverzerrungen geführt. So haben konventionelle Stromerzeuger durch einen Kompensationsmechanismus in Phase 2 einen Ausgleich für die Nettokosten der Zertifikate erhalten. Das hat den Anreiz zum Handel mit Zertifikaten entsprechend ihrer Grenzvermeidungskosten verzerrt und die notwendigen Emissionsminderungen auf teurere Optionen im Industriesektor verlagert. In umgekehrter Richtung führten die Auswirkungen anderer umweltpolitischer Instrumente im Stromsektor — vor allem hinsichtlich Feinstaubregelungen und erneuerbaren Energien — zu geringeren Emissionen im Jahr 2020, was wiederum zu einem wachsenden Überschuss an Zertifikaten und sinkenden KAU-Preisen beigetragen hat.

- **Vorhersehbarkeit:** Es gibt verschiedene Deutungsansätze zur langfristigen Ausrichtung des Preissignals unter dem K-ETS. Einerseits wird die kurzfristige Vorhersehbarkeit der Preise dadurch erschwert, dass der konkrete Reduktionspfad des Caps und die Kriterien für die kostenlose Zuteilung der Zertifikate erst kurz vor den entsprechenden Handelsphasen des K-ETS veröffentlicht werden. Zudem wird die Vorhersehbarkeit erschwert, da Eingriffe im Sinne der Marktstabilität größtenteils durch diskretionäre Maßnahmen erfolgen, da die Auswirkungen von begleitenden politischen Maßnahmen ungewiss sind und sich die politische Landschaft zugunsten einer ambitionierten Klimapolitik verschiebt, deren genaue Auswirkung auf die ETS Ausgestaltung aber noch ausgearbeitet werden muss. Die mittelfristige Vorhersehbarkeit der KAU-Preise hat sich jedoch mit der Veröffentlichung der überarbeiteten Treibausgas (THG)-Roadmap im Jahr 2018, die langfristige Emissionsminderungsziele pro Sektor festlegt, deutlich verbessert. Darüber hinaus ist davon auszugehen, dass sich die Vorhersehbarkeit der Preisentwicklung in Phase 3 (und 4) weiter erhöhen wird aufgrund einer generellen verbesserten Preisfindung und der potenziellen Einführung eines Terminmarktes.

- **Umweltwirksamkeit*:*** Die Umweltwirksamkeit eines ETS entspricht der Menge der vermiedenen Emissionen. Diese wurden in Südkorea durch die bindende Emissionsobergrenze und durch strenge Regeln für die Verwendung und die Zulassungskriterien für zusätzliche Bezugsquellen von Zertifikaten in Form inländischer und internationaler Offsets sichergestellt.

Auswirkung der Struktur des Strommarktes und seiner Regelungen auf das Minderungspotenzial im Rahmen des ETS

Das K-ETS hatte keine wesentlichen Auswirkungen auf die Emissionsminderungen im Stromsektor in den Phasen 1 und 2, da die Kosten der Zertifikatspreise nur unzureichend auf die Großhandelsstrompreise umgelegt wurden und die konventionellen Stromerzeuger für die Nettokosten der Zertifikate durch einen Kompensationsmechanismus entschädigt wurden, der außerhalb der Strompreisbildung wirkt. Durch die Einbeziehung großer Stromverbraucher in das K-ETS wird zumindest theoretisch ein gewisses Maß an Emissionsminderung in den nachgelagerten Bereichen ausgelöst, obwohl dieser Effekt vermutlich durch den hohen Anteil an kostenloser Zuteilung von Zertifikaten begrenzt wurde. Abhilfe schaffen könnten vor kurzem vorgeschlagene Strommarktreformen, die sicherstellenwürden, dass das ETS und der Stromsektor besser aufeinander abgestimmt sind. So soll ein ökologischer Dispatch-Mechanismus im Zeitraum 2022-2024 eingeführt werden, während parallel dazu eine weitere Preisliberalisierung im Rahmen der Schaffung eines preisbasierten Poolmarktes diskutiert wird. Beide Optionen werden es ermöglichen, dass sich die Nettokosten für Zertifikate im Stromgroßhandel widerspiegeln, wobei ein preisbasierter Pool ab 2025 möglicherweise die vollständige Umlage der CO_2-Kosten auf die Strompreise ermöglichen könnte.

- **Kapazitätsmix:** Der südkoreanische Strom-Mix wird zu einem etwa gleichen Anteil von Gas und Kohle dominiert, die zusammen fast zwei Drittel der gesamten installierten Stromkapazitäten ausmachen. Bei der Stromerzeugung dominieren Kohlekraftwerke, sie machten 2019 40 % der Gesamterzeugung aus. Erneuerbare Energiequellen sind in den letzten zehn Jahren exponentiell gewachsen und machten im Jahr 2019 6 % der Gesamtstromerzeugung aus. In diesem Zusammenhang besteht ein hohes latentes Potenzial für den CO_2-Preis, um Anreize für eine Brennstoffumstellung zu schaffen und das Wachstum der erneuerbaren Energien weiter anzukurbeln.

- **Alter der Kohlekraftwerke:** Südkorea hat relativ effiziente Kohlekraftwerke mit einem Durchschnittsalter von 16 Jahren. Kohlekraftwerke unterliegen Emissionsstandards, Feinstaubvorschriften, einem Auslaufplan mit zweckgebundenen Stilllegungen und Kohle-zu-Gas-Umrüstungen sowie einer Obergrenze für die Laufzeit von 30 Jahren. Die Obergrenze für den Lebenszyklus mindert in Kombination mit Kapazitätszahlungen das wirtschaftliche Risiko verlorener Vermögenswerte („stranded assets“), begrenzt aber auch die Rolle, die der CO_2-Preis als Anreiz für eine frühzeitige Stilllegung haben kann.

- **Begleitende energiepolitische Maßnahmen:** Das K-ETS wird zusammen mit einer Reihe von anderen energiepolitischen Instrumenten eingesetzt, wie z.B. Kapazitätszahlungen, Standards für erneuerbare Energien, Emissionsleistungsstandards, Brennstoffsteuern, Ausstiegsprogramme und Technologievorgaben. Mit Ausnahme des Ausstiegs aus der Kernenergie zielen alle diese Instrumente — wenn auch in unterschiedlichem Maße — auf die Dekarbonisierung des südkoreanischen Stromerzeugungsmix ab. Da im Rahmen aktueller politischer Maßnahmen bis 2034 mehr als 60 GW an erneuerbaren Energien in das Netz eingespeist werden sollen und der Anteil der Gaskraftwerke, die Kohlekraftwerke ersetzen sollen, steigt, wird der Bedarf an Emissionszertifikaten innerhalb des K-ETS im Stromsektor in den kommenden Jahren wahrscheinlich sinken. Strengere Verpflichtungen im Rahmen des Renewable Portfolio Standard (RPS), der Bestandteil des südkoreanischen

Green New Deals ist sowie die Aussicht auf weitere Anpassungen im Einklang mit einem Netto-Null-Emissionspfad, würden dazu führen, dass der Anteil der erneuerbaren Energien schon früher steigt. Das wiederum wird mit einer geringeren Nachfrage nach Zertifikaten einhergehen und sich negativ auf die ETS-Zertifikatspreise auswirken. Die Erhöhung der direkten Steuern auf den Kohleverbrauch ist ein weiterer Mechanismus, den Südkorea in Verbindung mit umweltfreundlichem Dispatch einsetzt, um den Umstieg auf Flüssigerdgas (*liquid natural gas* — LNG) zu fördern. In diesem dynamischen politischen Umfeld ist die Anpassung des K-ETS an den breiteren Policy-Mix von entscheidender Bedeutung, um ein glaubwürdiges Preissignal zu liefern, das Dispatch- und Investitionsentscheidungen steuern kann. Klare und transparente Maßnahmen zur Marktstabilität können dabei sicherstellen, dass das K-ETS angesichts von Anpassungen und Änderungen in anderen Politikbereichen relevant bleibt. Die Rolle des Komitees für die Zuteilung der Zertifikate und die Regeln, die vorschreiben, wann es in den Markt für Zertifikate eingreifen kann, könnten hierbei von regelmäßigen Überprüfungsrunden profitieren.

- **Umlage der CO_2-Kosten auf die Großhandelsstrompreise:** In den Phasen 1 und 2 des K-ETS spiegelte der regulierte Großhandelsstrompreis die Kosten für die Zertifikate nicht wider. Dadurch wurde das Potenzial für umweltfreundlichen Dispatch verhindert, während die Kompensation der Nettokosten für die Zertifikate die interne Rendite aus CO_2-intensiver Stromerzeugung aufrechterhalten hat. Der Vorschlag für einen umweltfreundlichen Dispatch sieht vor, dass die Nettokosten der Zertifikate im Systemgrenzpreis berücksichtigt werden. Eine mögliche Brennstoffumstellung unter diesem Mechanismus wird von einer beschleunigten Reduzierung der kostenlosen Zuteilung von Zertifikaten an den Stromsektor abhängen. Der vorgeschlagene ***ökologische Dispatch-Mechanismus*** kann auch die Erzeuger erneuerbarer Energien durch höhere Großhandelsstrompreise unterstützen, solange die Grenzerzeuger die Kosten für die Zertifikate tragen.

- Mit Blick auf die Zukunft würde ein vollständiger Übergang zu einem ***preisbasierten Pool*** ab 2025 die Möglichkeit bieten, die CO_2-Kosten vollständig an den Stromgroßhandel weiterzugeben und damit CO_2-arme Stromerzeugungsquellen im gesamten Kapazitätsmix zu unterstützen und das erhebliche Potenzial in Südkorea zur Brennstoffumstellung zu fördern. Die Erhöhung der CO_2-Kosten wird auch einen Anreiz für die Stromerzeuger schaffen, die Zertifikate entsprechend ihrer Grenzvermeidungskosten zu handeln, die Nachfrage nach Zertifikaten durch Emissionsminderungen zu senken und die Kosten, die mit den Erfüllungsverpflichtungen einhergehen, für andere vom K-ETS erfasste Sektoren zu reduzieren. In einem Szenario, bei dem die gesamten Kosten weitergegeben werden, können gezielte kostenlose Zuteilungen dazu beitragen, die schwindenden Erträge der konventionellen Stromerzeuger auszugleichen und den Übergangsprozess zu vereinfachen. In Verbindung mit Intraday-Preissignalen und der Einführung von gesonderten Märkten für Hilfsdienste könnte die Rolle des CO_2-Preises dahingehend erweitert werden, dass Anreize für Nachrüstungsinvestitionen geschaffen werden. Diese wiederum können die Flexibilität der Anlagen erhöhen und sicherstellen, dass einzelne Kohlekraftwerke weniger produzieren und zwar dann, wenn es am wichtigsten ist.

- **Umlage der CO_2-Kosten auf die Strompreise der Endverbraucher:** Das Potenzial für die Umlage von CO_2-Kosten ist in Südkorea eng mit der Reform der Strompreise verbunden und läuft auf eine politische Diskussion darüber hinaus, wer im Rahmen des K-ETS die Kosten für die Emissionsminderungen im Stromsektor tragen soll. Die Korean Electric Power Corporation (KEPCO), der einzige Abnehmer, sieht sich aufgrund höherer Systemgrenzpreise, die sie den Stromerzeugern zahlen muss, aber nicht vollständig durch schrittweise steigende Endverbraucherpreise decken kann, mit steigenden Kosten konfrontiert. Umgelegte Kosten für den Erwerb von Zertifikaten würden eine zusätzliche Kostenbelastung für KEPCO darstellen, die in den Phasen 1 und 2 des K-ETS von der Korean Power Exchange (KPX) durch den Kostenausgleichsmechanismus übernommen wurden. Die jüngsten Reformen der Stromtarife zur separaten Abrechnung der Kosten der Klimaauswirkungen werden die Kostendeckung unterstützen und könnten den Weg für eine vollständige Weitergabe des CO_2-Preises in den kommenden Jahren ebnen. Die schrittweise Einführung kostenorientierter Tarife für Dispatch und Endkundenversorgung wird im Laufe der Zeit einen Ausstieg aus der Einbeziehung indirekter Emissionen erfordern. In einem Szenario, in dem 100 % der Kosten für Emissionszertifikate weitergegeben werden, können kostenorientierte Endverbraucherpreise zudem an ein Rabattsystem aus den ETS-Einnahmen gekoppelt werden. Damit würde der Anreiz für nachfrageorientierte Maßnahmen erhalten und gleichzeitig die Kosten für einkommensschwache Gruppen oder vulnerable Industriezweige niedrig gehalten.

Da größere Reformen sowohl des K-ETS als auch des Elektrizitätssektors anstehen, werden die nächsten Jahre richtungsweisend für das Potenzial zu beschleunigten Emissionsminderungen durch das ETS sein. Dies wird nicht nur für den südkoreanischen Dekarbonisierungspfad von entscheidender Bedeutung sein, sondern könnte auch ein Beispiel für Länder sein, die die Einführung einer CO_2-Preispolitik erwägen, um damit die Dekarbonisierung in regulierten Stromsektoren voranzutreiben.

1 Introduction

The Republic of Korea (ROK, 2020) has committed to reducing emissions by 24.4% below 2017 levels by 2030 through its Nationally Determined Contribution (NDC) to the United Nations Framework Convention on Climate Change (UNFCCC).[1] The government launched the Korean Emissions Trading System (K-ETS) in the same year, the first of its kind in East Asia, to provide long-term policy direction for the energy-intensive sectors. Covering more than 70% of the country's greenhouse gas (GHG) emissions from the electricity, industry, buildings, waste, and (domestic) aviation sectors through a mandatory cap-and-trade system, the K-ETS has been designed as a key instrument to meeting Korea's climate mitigation targets (ICAP, 2020a).

Since its launch in 2015, K-ETS allowance prices have steadily increased, reaching more than EUR 30 toward the end of 2019, the highest price level among ETSs at the time (ICAP, 2020c). Despite increasing prices, the K-ETS has also experienced teething problems common to early phases of ETS implementation. High shares of free allocation combined with constraints on market participation have resulted in low levels of liquidity. However, as the K-ETS enters its third phase, key design changes to allowance allocation and rules surrounding market participation are expected to increase price discovery and therefore the quality of the allowance price signal. However, a critical question remains as to whether the K-ETS can influence production, investment, and consumption decisions within Korea's electricity sector, over which the government exerts a significant level of control.

Korea's electricity sector features limited wholesale competition and is centrally regulated with administratively set prices and government control over investments. The Ministry of Trade, Industry and Energy (MOTIE) sets the long-term direction of the sector through technology-specific targets and complementary policies, such as capacity payments, fuel taxes, and Renewable Portfolio Standards (RPS). The Third Energy Basic Plan, released in 2019, aims to increase the share of renewable energy generation to 20% by 2030 and 30-35% by 2040, reduce coal consumption to 24% by 2030, gradually phase down nuclear generation assets from 30% to 18% in the next decade, and increase the share of gas and reduce electricity demand by 15% in 2035 (MOTIE, 2019). This outlook is set to become more ambitious following the government's announcement in 2020 to reach carbon net neutrality by 2050. Decarbonising the electricity sector in this context will require substantial investments, both to replace the existing infrastructure and to meet electricity demand that is projected to grow by 1.6% per year.

The K-ETS has covered indirect emissions from electricity consumption of large buildings and other facilities to stimulate improvements in energy efficiency. Reflecting allowance costs in wholesale electricity prices is still a major challenge, one that must be overcome if the K-ETS is to play a stronger role in incentivising fuel switching and investment in low carbon generation. One promising approach under consideration at the time of writing would be to reflect allowance costs within the administratively set wholesale electricity price that is applied to rank generators for dispatch, otherwise known as "environmental dispatch". Renewed market liberalisation efforts are being discussed in parallel, and if advanced, would see competition in wholesale electricity generation strengthened (MoE 2020g; MOTIE, 2020b).

In this study, we assess in detail how design features of the K-ETS influence the quality of the allowance price signal, and how the latter is reflected in Korea's electricity markets and investment decisions. We assess the price signal across price volatility, reflection of MAC, long-term price predictability and environmental effectiveness criteria. We assess interactions of the price signal and electricity markets through their impact on dispatch decisions, demand-side

[1] Amounting to 536 $MtCO_{2e}$ by 2030.

response (efficiency) and low-carbon investment. Our analysis is grounded in the conceptual study of Acworth et. al (2019) “Influence of market structures and market regulation on the carbon market”, which forms the precursor to this work along with case studies in the European Union, China, Mexico, and California. The analysis provided here builds on (i) in-country interviews with stakeholders from the public sector, private sector, and academia, (ii) government projections, outlooks, and policies, (iii) carbon market data from the Korea Exchange (KRX) and power system data from *inter alia* the Korea Power Exchange (KPX), as well as (iv) wider carbon market and electricity sector literature.

The report is structured in three parts. First, the K-ETS, its most important design features, and the functioning of its carbon market are detailed. Second, we describe the Korean electricity markets in terms of design, participants, demand, supply-side structure and investment, and additional regulations. Third, we analyse the interaction between carbon and electricity market regulations. We discuss the impact of the carbon price on electricity sector abatement in the short run (fuel switch, energy efficiency) and long run (low carbon investment) and assess the implications of envisaged reforms to both the ETS and the electricity sector. In doing so, we contribute to a better understanding of the interactions of an ETS with electricity sector regulations that we hope is informative not only for the Korean debate but also for other countries considering an ETS but where market liberalisation is not foreseen in the near term.

2 Design and regulation of the Korean Emissions Trading System

2.1 Legal and policy framework

Since the 1980s, Korea has been implementing policies targeting energy efficiency and promoting renewable energy. At the 2009 Copenhagen Accord, the Korean government pledged —as a Non-Annex I country—to cap 2020 emissions at 30% below BAU. The 'Framework Act on Low Carbon, Green Growth' was enacted in the following year to provide a legal basis for implementing market-based climate and energy policies. Climate action plans were set out through the 'First Basic Plan for Climate Change Response' and '2030 Basic Roadmap for National GHG Mitigation' in 2016. President Moon Jae-in revised the latter in July 2018 stating that 32.5% out of the (then prevailing) 37%-below-BAU target for 2030 were to be met through domestic reductions, as opposed to 25.7% in the previous government plan.

Preceding the start of the ETS, the government launched the Target Management Systems (TMS) after a two-year pilot phase in 2012 to collect verified emissions data and train covered entities in monitoring, reporting, and verifying emissions data.[2] In the same year, the 'Act on the Allocation and Trading of Greenhouse Gas Emissions Permits' and 'Enforcement Decree of the Act on the Allocation and Trading of Greenhouse Gas Emission Permits' were enacted, providing the legal foundation for establishing the ETS. This was followed in 2014 by the release of the 10-year 'Master Plan for the Korea Emissions Trading Scheme' which outlines the strategy and ambition for the scheme across trading phases. The government limited initial trading phases to three years to facilitate learning and address design issues recently expanded to five years from Phase 3 (2021-2025) onwards (GIR, 2019).

Prior to each trading phase, the government releases a Basic Plan and an Allocation Plan, which together outline K-ETS implementation and allocation rules. The first of its kind were released late 2014 before the start of Phase 1 (2015-2017). The Second Basic Plan for the K-ETS was released in 2017 before Phase 2 (2018-2020). However, the Phase 2 Allocation Plan was delayed following the unanticipated presidential election in May 2017 that saw Moon Jae-in elected. The Ministry of Strategy and Finance (since 2018: Ministry of Economy and Finance (MOEF)), which at the time oversaw the K-ETS, decided in December 2017 to temporarily extend Phase 1 allocation rules to the second trading phase.

This political transition had two major consequences for the K-ETS. The first was a revision of ROK's energy-climate strategy that was first reflected in the 8th Basic Plan for Long-term Electricity Supply and Demand (BPLE) released by the MOTIE the same month as MOEF's decision to postpone allocation rules for Phase 2. The second consequence was an institutional restructuring, with the Ministry of Environment (MoE) regaining control of overall K-ETS policy and implementation from January 2018 onwards.

The MoE released the Auctioning Regulation for Phase 2 in May 2018, which took effect the following year, and revised the Offset Guidance to allow credits from international Clean Development Mechanism (CDM) projects in which Korean companies are involved. Two months later, the MoE published the delayed Phase 2 Allocation Plan jointly with the revised 2030 GHG roadmap reflecting the government's new climate policy direction. The former included downward corrections for 2018 allocations which were adjusted for in 2019 and 2020 allocations. The revised GHG roadmap provided sectoral reduction pathways and linked overall

[2] Since 2015, large companies and facilities are covered by the K-ETS, while the EMS continues to cover companies and facilities emitting less than 50,000 and 15,000 tCO_2/yr respectively.

cap-setting to the 2030 emissions target, thereby improving long-term direction. The Third Basic Plan for the K-ETS was released in December 2019. The third phase sees a shift from three-year phases to five-year phases to allow covered entities more long-term planning certainty and includes more stringent allocation rules and provisions for broader market participation. The government approved the Phase 3 Allocation Plan by late September 2020 after a two-month delay due to prolonged negotiations following divergent stakeholder views on benchmark revisions for the power sector.

2.2 K-ETS design overview

The K-ETS has several distinct design features, including broad sectoral coverage, high shares of free allocation, flexibility through banking, borrowing and offsets, relatively closed secondary markets, so-called Market Makers, and a discretionary body, an Allocation Committee, that can implement market stability measures (ICAP, 2020a). In addition to large emitters, the K-ETS also has surrender obligations for large buildings and other facilities, thereby also covering some indirect emissions. Table 1 summarises the system's main design elements. Below we describe each design element in more detail.

Table 1: Overview of K-ETS Design

Feature	K-ETS Design	Comment
Allowance cap	• Phase 1 (2015–2017): 1,686 $MtCO_2e$ • Phase 2 (2018–2020): 1,777 $MtCO_2e$ • Phase 3 (2021–2025): 3,048 $MtCO_2e$	• Excluding allowances for market stabilization and market makers (Table 2).
Long-term target	37% below BAU by 2030, representing a 22% reduction from 2012 GHG levels.	Net-zero target for 2050 has been announced
Primary allocation—in electricity sector	Phase 1: Grandparenting (GP), Benchmarking (BM) Phase 2: GP, BM (50%), auctioning (3%) Phase 3: GP, BM (60%), auctioning (10%)	Auction shares apply to sub-sectors subject to auctioning — 41 out of 69 in Phase 3.
(1) Banking **(2) Borrowing**	(1) Allowed (2) Allowed	(1) Limitations within and across phases (2) Within phases with limitations
Additional sources of supply	Phase 2: Offsets up to 10% of entities' compliance obligation Phase 3: Capped at 5%	• Phase 2: Korea Offset Credits (KOCs); International credits (CERs from Korean origin) up to 5% • Phase 3: no separate limit for international credits

Feature	K-ETS Design	Comment
Market stability mechanism	• Auction Reserve Price • Reserve for market stability and discretionary measures	• Changes – set by formula • ~5% of annual budget • Decided by Allocation Committee
Voluntary cancellation	n.a.	n.a.
Coverage	73.5% of GHG emissions. Heat and power, industry, buildings, domestic aviation, waste and public services sectors. These are disaggregated into 69 subsectors in Phase 3.	Covers CO_2, CH_4, N_2O, PFCs, HFCs, SF_6
Market participation	Phase 2: Limited to covered entities and three policy banks. Phase 3: Market open to third-party participation	Market makers: The Korea Development Bank; Industrial Bank of Korea; Korean Export-Import Bank
Legal nature of allowance	Property right	Art. 345 of the Korean Civil Law
Fiscal nature	KAUs are exempted from value added tax and not regulated under financial market law. Capital gains on KAUs are subject to corporate tax.	
Market place	OTC, spot (KRX). Futures contracts under development in Phase 3	
Transparency and market oversight	Regular release of information on important metrics related to the K-ETS: • MoE releases regular information on allowance allocation and verified emissions. • Greenhouse Gas Inventory and Research Center of Korea (GIR), an organisation under the MoE provides information on transactions (OTC and on the secondary market), surrendering of allowances, sanctions, and price developments. • The KRX has public and continuously updated information on allowance prices.	

2.2.1 Allowance cap and long-term targets

The K-ETS cap is published as part of the Allocation Plan, which is released at the beginning of each trading phase. The Allocation Plan includes annual caps and announcements of reserves set aside for market stability and new entrants. In Phases 1 and 2 of the ETS, annual caps have remained reasonably stable, varying between 540 and 609 $MtCO_2$ including indirect emissions (Table 2), which in Phase 1 accounted for 17% of covered emissions (GIR, 2020). About 1% of total allowances Phases 1 and 2 was set aside for market stability measures. Average annual allowance allocation in Phase 3 is set at 609 $MtCO_2e$, reflecting an increase in the system's scope to construction and transport companies and is in line with a cap reduction of 4.7% compared to 2017-2019 baseline emissions (ICAP 2021). Long-term targets for the ETS may be adjusted in the coming years to align with the net zero emissions target for 2050.

Table 2: K-ETS available allowances – million tonnes of CO_2

	Phase 1			Phase 2			Phase 3
Year	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021–2025**
Final allocation (includes allowances from the reserve used for early reduction, new entrants, and other purposes)	540.1	560.7	585.5	601.0	587.6	545.1*	609.7**
Cap	**1686.3**			**1777.1**			**3048.3**
Reserve for market stabilisation	14.3			14			14
Market Makers				5			20
Total (by phase)	**1700.6**			**1796.1**			**3082.3**

Source: Authors' elaboration based on data from the Third Basic Plan K-ETS, the 2020 GIR K-ETS Summary Report for 2018, and own calculations.
*Based on GIR (2020b) as of December, final allocation may be subject to change. Unallocated allowances are placed in a reserve.
** Annual average allowances as reported by the MoE (2020e; 2020g).

2.2.2 Initial allocation of allowances

Most allowances in the K-ETS are allocated free of charge. In Phase 1, allowances were mainly allocated through grandparenting, product-benchmarks applied to covered entities from the aviation, cement, and oil refinery sectors (Lim, 2015). Benchmarking was expanded to seven sectors in Phase 2 with the addition of waste, industrial parks, electricity generation and district heating/cooling[3] (MoE 2018). It was expanded further to a total of 12 sectors in Phase 3 with the addition of the steel, petrochemical, buildings, paper, and wood industries (MoE 2020g). Benchmark stringency in Phases 1 and 2 of the K-ETS reflected the median emissions intensity of facilities within a sector (MoEF, MoE, 2019). According to the Allocation Plan, benchmarking should cover 50% of primary allocation towards the end of Phase 2, rising to 60% in the third trading phase. The base year periods are 2014-2016 and 2017-2019 respectively.

Technology-specific benchmarks apply to power generation since the second trading phase. Coal benchmarks are tightened in Phase 3, while LNG benchmarks are set to become more generous from 2024 onwards, possibly as part of the introduction of a uniform benchmark for both fuel sources.

[3] Group energy describes energy that is not supplied to individuals but rather to a group or district such as apartments or industrial complexes.

Table 3: Electricity sector benchmarks in Phase 2 and Phase 3

Technology by fuel source	Phase 2 – '18-'20	Phase 3 – '21-'23	Phase 3 – '24-'25 Option 1	Phase 3 – '24-'25 Option 2	Unit
Coal power plant	0.8870	0.7874	0.6822	0.7087	tCO_2e/MWh
LNG combined heat and power plant	0.3889	0.3997	0.6822	0.4545	tCO_2e/MWh
Heavy oil power plant	0.6588				tCO_2e/MWh

Source: MoE 2018; 2020g.

The benchmark options for the second half of the third trading phase are tied to newly proposed electricity sector reforms. A uniform benchmark (option 1) will be introduced under current regulations with the possible implementation of an environmental dispatch mechanism starting 2024 (see section 5.2.2 below). Converging fuel benchmarks (option 2) would be introduced if plans for introducing a price-based pool (PBP) market and a cap on coal generation output are implemented by 2023 (MoE, 2020g). The impact of these options on electricity sector abatement are analysed in further detail in chapter 5.

Regular allowance auctions were introduced in Phase 2, the first being held in January 2019. The share of auctioning will increase from 3% to at least 10% of allocation to eligible entities in Phase 3. Participation in auctions is subject to some limitations. 26 (of 62) sub-sectors from power, industry and buildings could participate in auctions in Phase 2. In practice, the power sector has dominated auction bids given its shortfall from benchmarked allocation (GIR 2020). In Phase 3, 41 (of 69) industries are included in the auction scheme. Sectors considered to be at risk of leakage[4] continue to receive allowances for free and are not allowed to participate in auctions. Public sector entities such as local governments, hospitals, schools, and transportation operators will continue to receive 100% free allocation independent of leakage risks (MoE, 2020e).

To avoid the abuse of market power, no bidder can purchase more than 15% of the allowances auctioned. Auctions are also subject to a minimum price that will be set by the following formula: the average price over the previous three months + the average price of last month + the average price over the previous three days/3 (see ICAP, 2020a). While bids at K-ETS auctions have generally been above the auction reserve price, some auctions have failed to sell out due to the bidding limits. Unsold allowances are added to the next month's auction volume.

2.2.3 Banking and borrowing

Banking and borrowing are allowed within the K-ETS, but with restrictions that have evolved since the launch of the system. Changes to the rules surrounding banking and borrowing have been made with market stability and transparency concerns in mind.

Unlimited banking was allowed within the first trading phase and initially for Phase 2 until changes were made in May 2019. From Phase 1 to Phase 2, facilities could bank 10% of their average annual allocation at a maximum of 20,000 KAUs. The new rules for within-phase trade stipulate that banking is limited in proportion to an amount that an entity sells. Large industries

[4] Defined by the following formula: trade intensity * cost incurred ≥ 0.002

negotiated exceptions to the rules for allowances that were purchased before the new rule took effect. Specifics on the selling-banking proportions are as follows (see ICAP 2021):

- for KAU18s[5] it is possible to bank either three times the net selling amount *or* 75,000 tonnes for companies emitting >125k tCO_2e (or 15,000 tonnes for companies emitting >25,000) – whichever of the two is higher;
- For KAU19s the amounts above are reduced by 1/3, i.e. two times or 50,000 (10,000 for smaller entities) tonnes, again whichever is higher;
- For KAU20s the amount represents a 2/3 reduction compared to the KAU18 rule (Ecoeye 2019a).

To encourage allowance trade, carry-over banking between Phase 2 to Phase 3 was limited to 250,000 and 5,000 KAUs at company and facility level, respectively. The following rules apply for banking within Phase 3 (see ICAP 2021):

- In the first and second compliance years (2021-2022), entities can bank up to two times their net amount of allowances (KAUs) and offsets (Korean Credit Units, KCUs) sold on the secondary market.
- In the third and fourth compliance years (2023-2024), entities' banking limits equal their net amount of allowances and offsets sold.

In the fifth trading year of Phase 3, allowances and offsets can only be carried over to the first compliance year of Phase 4 (2026-2030) limited to an entity's annual average net sold units on the secondary market during the third trading phase (KAU21-KAU25; KCU21-KCU25).

Limited borrowing is also allowed within trading phases, with the borrowing limit being revised initially from 10% in 2015 to 20% in 2016 and 15% in 2018. From 2019, the limit of borrowing for each facility was based on previous years' borrowing as a proportion of firm level emissions.[6] At the start of Phase 3, the borrowing limit reverted to 15%, but the same formula will apply again in subsequent trading years. Borrowing across phases is not allowed.

2.2.4 Provisions for additional allowances supply

In Phase 2, K-ETS entities could meet up to 10% of their compliance obligation with credits generated outside of the ETS in the form of domestic Korean Offset Credits (KOCs) or overseas credits —the latter being limited to 5% of verified emissions. In Phase 3, a quantitative limit of 5% applies irrespective of offset origin. Renewable energy producers can decide whether to claim a renewable energy certificate (REC) or an offset credit.

Since Phase 2, Certified Emission Reductions (CERs) from CDM projects implemented in Least Developed Countries and operated by Korean companies are allowed if they meet one of three specific criteria: (1) at least 20% of the ownership rights, operating rights, or voting stocks are owned by a Korean company; (2) a Korean company delivers goods or services worth more than 20% of the total project cost; or (3) the projects are funded by a Korean company with a national or regional government operating in a UN-designated Least Developed Country or a low-income economy as classified by the World Bank (see ICAP, 2020a).

International offsets are limited to 5% of entities' compliance obligations in Phase 2 and 3. These are cancelled and converted into KOCs when entering the Korean market. A second conversion

[5] The 18 refers to the 'vintage' of the allowance, see section 2.2.7 for an explanation.

[6] According to the follow formula: [Borrowing limit of previous year - ("borrowing ratio" in previous year x 50%)]/entity's emission volume (ICAP 2020a).

process from KOCs to Korean Credit Units (KCUs) regulates offsets use for ETS compliance; this is managed by the MoE (ADB, 2018). The first batch of Korean-owned CDM projects was approved in early 2020, with CDM units starting to enter the system later the same year. KOC prices have largely followed regular allowance prices although market transparency is hindered by the share of units being traded outside of the KRX (Figure 3).

2.2.5 Market stability mechanisms

The provisions for price predictability in the K-ETS combine automatic and discretionary approaches. The government sets aside a certain amount of allowances from each trading phase in an allowance reserve. The allowance reserve provides additional allowances for new entrants but can also be accessed by the Allocation Committee for purposes of market stability. Specifically, the Allocation Committee may intervene in the market where (see ICAP 2021):

1. the market allowance price of six consecutive months is at least three times higher than the average price of the two previous years;
2. the market allowance price of the last month is at least twice the average price of the two previous years and the average trading volume of the last month is at least twice the volume of the same month of the two previous years;
3. the average market allowance price of a given month is smaller than 40% of the average price of the two previous years; or
4. it is difficult to trade allowances due to the imbalance of supply or demand.

The stabilisation measures may include:

1. the additional allocation of allowances up to 25% of the reserve's volume;
2. the establishment of an allowance retention limit: minimum (70%) or maximum (150%) of the allowance of the compliance year;
3. an increase or decrease of the borrowing limit;
4. an increase or decrease of the offsets limit; and
5. the temporary setup of a price ceiling or price floor.

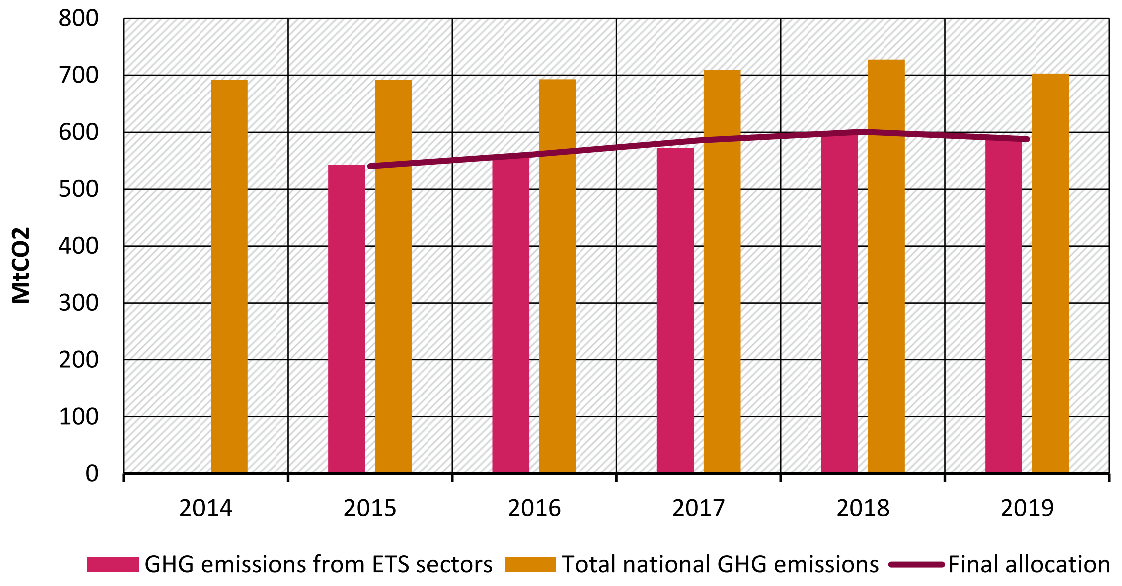
In 2016, the Allocation Committee doubled the borrowing limit to 20% and an additional 0.9 million allowances were auctioned at a reserve price of KRW 16,200 (EUR 12.36) of which fewer than a third were sold. In 2018, the Allocation Committee made an additional 5.5 million allowances available from the stability reserve in an attempt to ease the market in the lead-up to the 2017 compliance deadline.

On 10 June 2019, the Korea Development Bank and the Industrial Bank of Korea were officially designated as Market Makers, the sole third-party participants in Phase 2 along with the Korean Export-Import Bank. These institutions can draw on a separate government-held reserve of five million allowances, set aside at the time of original allocation, to increase liquidity in the market through daily allowance trade.

2.2.6 Coverage and compliance

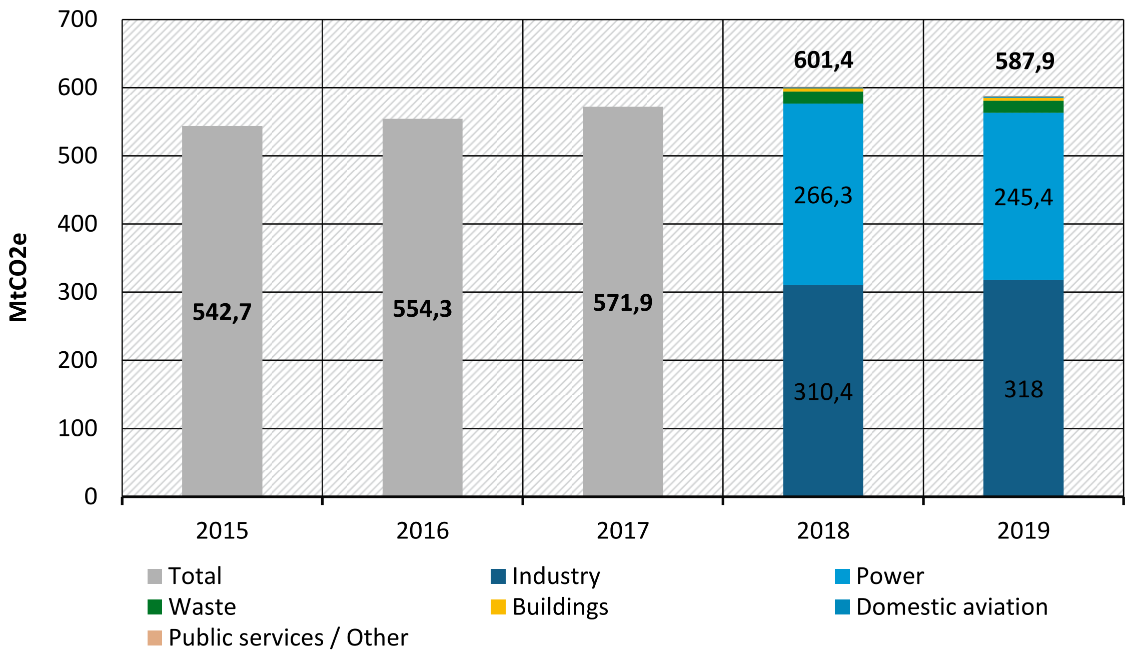
The K-ETS covers heat and power, industry, buildings, domestic aviation, waste and public services. These six sectors were broken down into 23 sub-sectors in Phase 1, increasing to 62 in Phase 2 due to a different disaggregation method and to 69 in Phase 3 following the inclusion of additional industry activities. Total emissions coverage (Figure 1) is expected to rise from 70.1% in Phase 2 to 73.5% in Phase 3 —i.e. excluding indirect emissions. The number of companies participating in the K-ETS has risen accordingly, from 522 in 2015 to about 610 by 2019 and 685 in 2021.

Figure 1: ETS and national GHG emissions (including indirect emission coverage)



Source: Authors' elaboration based on MoEF and MoE (2018); GIR (2019).

Figure 2: Certified emissions of K-ETS covered entities 2015-2019



Source: Authors' elaboration based on data from GIR, 2020; 2021

While industry on aggregate accounts for the majority of emissions covered by the K-ETS, the electricity sector is the single largest source of emissions in the system (Figure 2).

Companies emitting more than 125,000 tCO_2/year and facilities having emitted more than 25,000 tCO_2/year over the last three years are obliged to participate in the ETS. The same thresholds apply to consumers of electricity and heat, whose indirect emissions are calculated by multiplying consumption levels with the average carbon intensity of electricity generation. Companies, facilities, and consumers participating in the K-ETS must submit verified emission reports by the end of March for the previous compliance year. Following certification by the MoE in May, entities must surrender KAUs in June, six months after the reporting period, and at a fine of KRW 100,000 (EUR ~78) for each tonne of emissions not surrendered.

2.2.7 Trading and market participation

Market exchange takes place on the KRX, which is the designated spot market for the ETS, and through OTC transactions (KLRI, 2017). KAUs, KCUs and KOCs can be traded on either market. KOCs were initially excluded from spot trades and have since 2016 been listed to promote transactions on the KRX. Offset generators that have an account on the KRX are not allowed to trade KCUs and KAUs (Reklev, 2015).

Until Phase 3, market participation was limited to K-ETS covered entities and three designated policy banks. In Phase 3 brokerage firms and financial institutions will be allowed to trade emissions permits and converted carbon offsets on the KRX (ICAP 2020b). In Phase 1, the vintages available (KAU15, 16 and 17) were all tradable from the beginning of the phase and were subsequently delisted when the respective compliance deadline passed (June of the following vintage year). The same rules apply for Phase 2 vintages. KCUs are only tradable from Jan 1st of the respective vintage year until the compliance deadline for that trading year. KOCs have no vintage and as such have been tradable since the beginning of Phases 1 and have not been delisted.

2.2.8 Legal nature of allowances

The Act on the Allocation and Trading of Greenhouse-Gas Emission Permits[7] has no clause outlining the legal nature of allowances or referring to property rights. However, as outlined in a report commissioned by the Korean Ministry of Strategy and Finance, "[f]rom a legal point of view, the emission right has the property of property right because it satisfies both elements of the property right: private usefulness and disposability specified in the constitution" (Kim et al., 2017).[8] The legal basis stems from the Korean Civil Act,[9] where article 345 provides the basis for a pledge, a security (in this case the permit) for the performance of an act (in this case the right to emit), to also be recognised as a property right. The articles under the Civil Act apply, *mutatis mutandis,* to the provisions for pledges under other acts (Civil Act, Art. 344). As the legal basis is not directly mentioned in an act specifically pertaining to the K-ETS, legal experts interviewed for this report expressed concerns that the absence of an explicit qualification of the legal nature of allowances in Korean law could create a certain degree of uncertainty that could undermine the integrity of the market.

2.2.9 Fiscal nature of allowances

In Korea, the KAU is VAT-exempt and currently not regulated under financial market law, though capital gains on KAUs are subject to corporate tax.[10] Furthermore, derivatives currently are not allowed in the K-ETS but may be introduced in Phase 3 (MoEF, MoE, 2019).

[7] Available: http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/laws/1647.pdf

[8] Translated from Korean.

[9] Available: https://elaw.klri.re.kr/eng_service/lawView.do?hseq=29453&lang=ENG

[10] Indicated to the authors by the KRX in correspondence with the Korea National Tax Service

2.2.10 Transparency of regulation

Public authorities have since the start of the K-ETS consistently shared market information. The KRX, the designated secondary market servicing the system, provides publicly available information on prices and trading volumes of current and future vintages as well as offsets on a live basis.[11]

The MoE, the K-ETS responsible body, consistently conveys changes, amendments, updates, and new information pertaining to the system through running press updates, numbering over 35 since the system was first legislated.[12] The press updates include in-depth documents fleshing out the often-summarised press information. Most importantly the MoE regularly provides information on allowance allocation and verified emissions, immediately when available from the Greenhouse Gas Inventory and Research Center (GIR). An agency of the MoE, the GIR operates Korea's monitoring, reporting and verification (MRV) system and conducts extensive scientific research. As part of its research, which collates statistics from several ministerial sources, the GIR synthesises and presents summary reports of the K-ETS outlining the key developments in the system (GIR 2019, 2020). The reports draw on interviews with covered entities highlighting trends and providing insightful information helping to increase the system's overall transparency.

The type of information and the frequency with which it is released can impact the market via expectations of scarcity. A high reporting frequency and therein increased transparency can reduce volatility, improve information surrounding MAC, and generally increase predictability (Acworth et al., 2019, p. 20), effects expected to have occurred in the K-ETS through the aforementioned reporting practices.

In the next chapter we assess how design features of the K-ETS have impacted the market and analyse the quality of the price signal along four criteria: volatility, reflection of MAC, long-term predictability, and environmental effectiveness.

[11] With a 20-minute delay. Available here.

[12] A search on the MoE's website for "Emissions Trading" provides an insight into their press communications.

3 K-ETS design impact on the allowance price signal

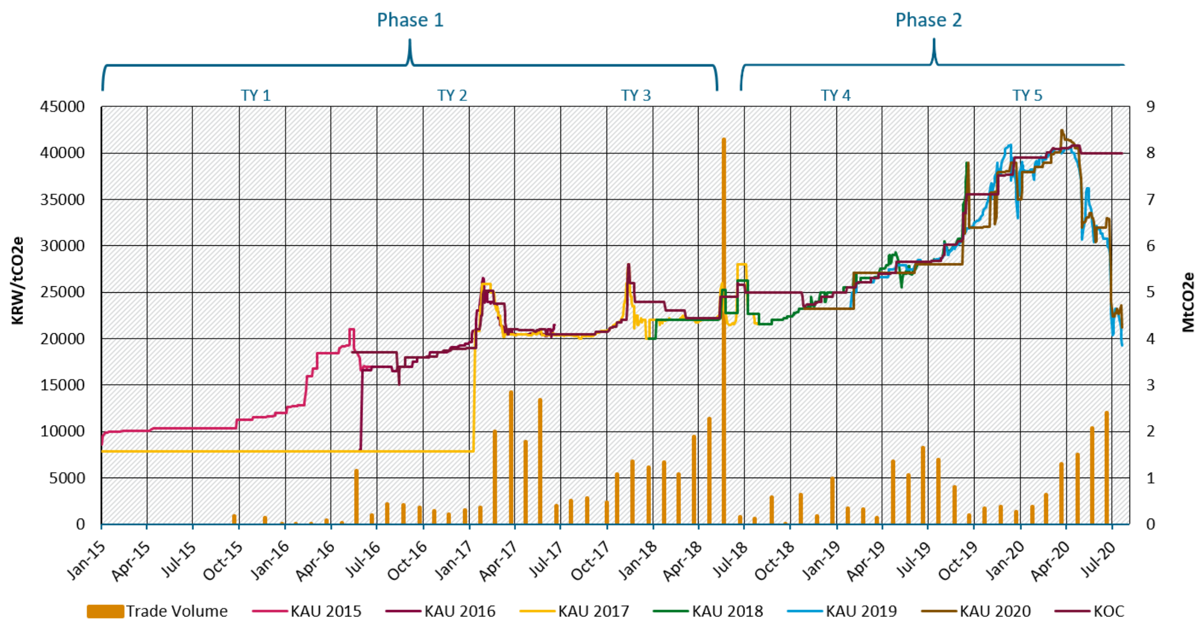
3.1 Development of the price signal in the K-ETS

KAU prices steadily increased since the launch of the system in 2015 reaching KRW 40,900 (EUR 31.7) in late December 2019 before dropping to levels around KRW 20,000 (EUR 14.2) towards the end of the compliance cycle in July 2020. In general, the upward price trajectory observed until 2020 has been characterised by a series of "price peaks" where prices rise quickly to a high for the trading year, before declining quickly and continuing along the upward trend.

Price peaks have been associated with rule adjustments. This has been most visible in Phase 1, where market interventions in the form of revised rules on banking and borrowing and additional auctions from the allowance reserve targeted concerns over net scarcity. In addition, authorities eased policy uncertainty by reassuring market participants that additional allowance would be released in case of shortage. Stricter allocation quotas and more ambitious sectoral emission reductions targets then accelerated price increases in Phase 2. This trend reversed from May 2020 onwards, when a surplus of allowances resulting from emission reductions in the electricity sector and the impact of COVID-19 pushed prices down to levels not seen since 2017.

In this environment, it is likely that price fluctuations in the K-ETS have largely been driven by regulatory changes and external shocks and less so by financial trading given market constraints. These dynamics, as well as those driving a reversed market outlook in 2020, are described in further detail below before we analyse in chapter 3.2 the impact of K-ETS design features on volatility, MAC, predictability, and environmental effectiveness.

Figure 3: K-ETS prices and aggregated monthly trade volumes



Source: Authors' elaboration based on market data from KRX (2020).

3.1.1 Phase One

Allowances were first traded on the KRX for KRW ~8,700 (EUR 7) in January 2015 and hovered around KRW 8,700-11,000 (EUR 7-9) before picking up in the following year. Market participants largely refrained from trading in the first half of 2015 following fears among industry over insufficient allocation and legal complaints to the MoE, which resulted in a flat price curve for those months. Allowance trading resumed in October 2015, albeit at low levels. In a move to boost trading activity and address market concerns over allowance supply, the MoE listed KCUs on the exchange in April 2015 and issued 1.91 Mt offset credits (MoE, 2015), the majority of which were traded on the OTC market (Ecoeye, 2018a). In May 2016 the government introduced further reforms and listed KOCs on the KRX. At the same time the Allocation Committee doubled the borrowing limit and auctioned a batch of 900,000 allowances from the reserve. These measures saw allowance prices on the KRX temporarily decrease after having reached the first peak at KRW 21,000 (EUR 15.7) in late May that year.

With concerns about a supply imbalance lingering into the second trading year, prices picked up again in Q4 2016 and rose to a new high in February 2017. At their peak, KAU16s closed on the KRX at KRW 26,500 (EUR 21.6) for two consecutive days. Prices increased despite the government's announcement in the preceding month that 14 million additional allowances were to be supplied in the third trading year—more than 80% of which would be allocated to the manufacturing sector—and 51 million early action credits would be released from the reserve (MoEF, 2017). Trading activity rose during the second compliance period of March-June 2017 which coincided with new carry-over banking limits (Phase 1 – 2) that were released in April 2017 and stimulated selling of banked allowances. At the same time, the 20% borrowing limit relaxed demand on the market as entities seeking to secure additional allowance for compliance had different avenues through which to do so. Both factors likely resulted in a moderate drop in the allowance price seen in KAU16s closing at KRW 21,500 (EUR 16.5) toward the end of the second compliance cycle.

As mentioned in Chapter 2.1, the second half of 2017 saw a reshuffling of ministerial responsibilities over the K-ETS and a delay in the release of the Phase 2 Allocation Plan and offset rules. While MOTIE was developing the 8th electricity supply plan, which was anticipated to introduce more ambitious low-carbon energy targets, prices of KAU17s peaked in late November 2017 to KRW 28,000 (EUR 21.8). Pressure on the market was eased when the government shared a draft Allocation Plan with compliance entities at the end of November with the reassurance that reserve allowances would be supplied to the market in case of a supply imbalance (Ecoeye, 2018a). In the months following, prices on the KRX stabilised around KRW 22,000 (EUR 16.78) and became more volatile toward Phase 1's final compliance period, which saw record trade activity and high demand. A price peak at the end of May 2018 of KRW 26,000 (EUR 20.44) and high demand in the lead-up to the compliance deadline led the Allocation Committee to auction off 5.5 million allowances from the stability reserve on the June 1st, out of which 85% was sold at the reserve price of KRW 22,500 (EUR 17.58). Another price peak occurred at the very end of the 2018 compliance cycle in late June when prices reached KRW 28,000 again (EUR 21.55). This time this was accompanied by the MoE's draft release of the revised 2030 roadmap, which put forward increased emission reduction targets for the ETS covered sectors.

3.1.2 Phase 2

KAU18 prices peaked well into July 2018 before stabilising around KRW 22,000 towards the end of the month, reflecting lower demand and a portion of carry-over KAU17s offered on the market (Ecoeye, 2018b). Prices averaged KRW 21,700 (EUR 16.70) in Q3 of 2018, during which the Phase 2 Allocation Plan was released (July 2018) and the final allocation quotas were settled (late October). In Q4 of 2018, increasing demand for KAU18 allowances and few sell orders—

most large transactions were concluded on the OTC market— led prices on the KRX to increase and close at KRW 25,000 (EUR 19.56) on December 31st (Ecoeye, 2018c).

Regular auctions commenced in January 2019, supplying between 550,000-1,000,000 allowances to the market each month. Nonetheless, KAU18 prices peaked in February as the auction cleared above the market price. KAUs further climbed to KRW 29,000 (EUR 22.58) toward the end of April and reached a new high of KRW 29,300 (EUR 22.16) in early May 2019 (KRX, 2020). From April onwards, active trading increased as the ensuing high price environment started to stimulate long selling. Companies that had taken long positions further boosted their supply to the market in anticipation of carry-over restrictions within Phase 2, which were announced to be released during a public hearing on May 21st, 2019. On the back of additional selling, KAU18s dropped to KRW 25,500 (EUR 19.24) the day preceding the announcement (Ecoeye, 2019a). The MoE eventually revealed banking limits would be proportionate to an entity's selling quantity and take effect the same month (see rules in Chapter 2.2.3). In this light, the Ministry extended the 2018-2019 compliance deadline to the end of August so as to allow more time for trading and banking/borrowing applications (Ecoeye, 2019a). In line with previous years, market liquidity increased towards the end of the compliance period as entities sought to balance trading accounts. KAUs were traded on the exchange for KRW 27,500-29,850 (EUR 21.40-22.60) during compliance months and continued to rise at an accelerated pace at the start of the new compliance cycle in September 2019.

Overall, market sentiment remained bullish, in part fuelled by the MoE's decision to implement banking restrictions—instead of releasing additional allowances to the market—and stricter allocation quotas in second trading phase. Taken together, in addition to the certainty provided from the broader regulatory framework, these factors sharply drove up demand in Q4 of 2019 as entities sought to secure KAU19 allowances early on. Although the market makers—which started trading in June—now offered daily supply volumes on the exchange, overall supply rates dropped to 15.2% in October driven by high demand (Ecoeye, 2019b). Prices rose to around KRW 39,000 (EUR 29.75) toward late November before reaching their highest peak of KRW 40,900 (EUR 31.40) on December 23rd (KRX, 2020).

Figure 3 shows that Korean allowance prices initially remained stable in the face of a low oil price environment and the economic downturn following the COVID-19 outbreak. KAU prices hovered around KRW 40,000 (EUR 29) amid the crisis in February-April 2020, with the April auction clearing at the highest price observed (KRW 41,000 (EUR 30.82)) since regular auctions commenced in January 2019. In the same month, Korean authorities announced that the compliance period would be extended and revised the monthly auction schedules in the run-up to the end of the 2019 compliance year (Ecoeye, 2020). The market first started to react in May 2020, with KAUs following a more volatile price trajectory than in the preceding months. KAU prices dropped to a low of KRW 31,000 (EUR 22.93) by May 13th and climbed back up to KRW 36,000 (EUR 27.03) toward the end of the month only to fall back to KRW 30,400 (EUR 22.34) in early June (ICAP, 2020c).

A reversal of market dynamics

The market's slow response can be partly attributed to risk-averse behaviour that saw few entities sell surplus allowances. More importantly, covered entities were mainly focussed on surrender obligations for the 2019 compliance year, which initially featured a high demand for KAU19 allowances. The MoE's release of the verified emissions reports in May 2020, however, indicated emissions covered by the ETS to be 2% lower than the previous year, mainly driven by an 8.6% reduction in power sector emissions (MoE, 2020b).[13] With an estimated net surplus of 8

[13] A later update revealed total emissions to have declined by 3.4% compared to 2019 (MoE, 2020f).

million allowances, the market was no longer short. This update came against the backdrop of lower emissions projected for 2020 due to the economic impact of COVID-19, leading to additional surplus. As can be observed in Figure 3, KAU prices dropped to below KRW 20,000 (EUR 14.2) by the end of July, reflecting a diametrically reversed market outlook. Prices stabilised around KRW 22,000 thereafter. In the following section, we will assess how the K-ETS's design has impacted the quality of the allowance price signal.

3.2 Assessment of the allowance price

3.2.1 Volatility

As described in Chapter 3.1.1, KAU prices followed a relatively stable upward price trajectory until May 2020, interrupted by price peaks either caused by high allowance demand in the lead up to the compliance deadline or by perceived scarcity on the market. Frequent policy announcements have served to alleviate such market concerns, resulting in temporary relief before prices picked up again. Apart from these recurring price peaks, volatility remained moderate in the K-ETS's first year but increased towards the end of Phase 2 driven by external shocks.

Low market liquidity, a key driver of KAU price developments, has been a consistent feature of the system. Contrary to the EU ETS, where market reforms have been targeted at reducing oversupply, interventions in the K-ETS have aimed to activate the market. In the latter, only 3% of total allocated allowances were traded in Phase 1, compared to just under 25% for the EU ETS in its first trading phase.[14] A combination of high shares of free allowance allocation, limited market participation and high volumes of OTC trade, frequent changes to rules surrounding banking and borrowing, as well as limited transparency surrounding future allowance scarcity have contributed to low liquidity and limited price discovery. Collectively, these design features have likely contributed to some excessive volatility over short time windows, particularly surrounding compliance periods and new policy announcements.

Table 4: Trading activity* in the K-ETS in 1,000s of tonnes

Vintage	Intra-market transaction (KRX)		OTC		Sum traded	Cap	Trade volume as percentage of cap
	Competitive Trade	Block trade**	Standard deals	Swaps and other transactions			
KAU 15	336	1,010	286		1,632	540,100	0.30%
KAU 16	2,450	6,543	4,573		13,566	560,700	2.42%
KAU 17	6,338	10,752	8,794	9,430	35,314	585,500	6.03%
KAU 18	3,229	4,291	7,105	13,916	28,541	593,500	4.81%

Source: Authors' elaboration based on information from the 3rd Basic ETS Plan (page 6)
*Trading of KCUs and KOCs are not included in the trading figures

**Block trade refers to an exchange-based OTC market transaction where the bidder enters their preferred purchase amount and the price they are willing to procure for. The advantage is that

[14] Own calculations based on allocation data from the EEA EU ETS data viewer and trade data from the European Commission.

the offers are not limited by amount nor are they subject to price fluctuations of the intraday market. More information (in Korean) on the distinction between the two types of intra-market transactions can be found on slide 10 here by the Industrial Bank of Korea.

Table 4 above indicates that trade activity has moderately increased over the first four trading years as the system matured and policy interventions aimed at stimulating trading bore effect. Nonetheless, trading shares as a percentage of allocation have remained within single digits into the second trading phase. Anecdotal evidence from interviews suggests that low trade volumes may result from companies borrowing from future allocation to meet current compliance needs as well as engaging in OTC transactions that are not recorded in the exchange.

High shares of free allocation are a key driver of the low market liquidity observed in the K-ETS, primarily by limiting participants' need for engaging in market transactions.[15] These dynamics temporarily reverse around the end of the compliance period, by which point covered entities have reported on their previous' year's emissions and seek to balance their market position by either buying or selling allowances. Covered entities with surplus allowances have often held on to allowances in Phases 1 and 2,[16] due to an overall bullish market outlook until 2020 and risk-averse market behaviour (Chapter 3.2.2). This has resulted in periods of low seller's liquidity and high allowance demand that have largely driven the price peaks analysed in the previous section. Given the closed market system, there has been no participation of financial intermediaries in the first and second trading phases to counteract these dynamics and facilitate higher trading volumes throughout the year. The planned introduction of extended third-party participation will help improve market liquidity.

There have been no forward prices for KAUs due to the nature of trading being limited to intraday and OTC markets. This has helped curb financial speculation but has given more prevalence to compliance-focussed transactions, and lower overall trading levels. Market liquidity constraints also stem from a preference among companies to engage in OTC transactions over spot trading (

Table 4). According to interview participants, this mostly concerns large entities that have been able to establish reliable trading partners, decreasing their need for spot trades while avoiding exchange-based fees. During compliance months, exchange trading usually dominates regardless of company size. However, higher volumes of OTC trading have reduced potential trade activity on the spot market that disproportionately represents small transactions. This is likely to have rendered exchange trade more volatile (KRX, 2020).

Experts interviewed for this study indicate that the designated Market Makers have been able to countervail liquidity constraints by engaging in simultaneous selling and buying in the market, which is seen to have reduced the bid-ask spread and improve trade activity on the exchange (GIR, 2020a). Still, trading volumes from Market Makers, representing 0.5% of KAU18 sales (ibid), are regarded as insufficient to address the root causes of low market activity. Price discovery may improve considerably in Phase 3 with the expansion of auctioning, reduction of free allocation and the introduction of third-party participation in exchange trading, allowing financial actors to trade environmental commodities and act as financial brokers (MoE, 2020a). There are, however, some potential effects to consider to ensure the K-ETS drives emissions reductions at least cost.

[15] Indicated by experts interviewed for this case study.

[16] Indicated by experts interviewed for this case study.

3.2.2 Reflection of MAC

Before the onset of the COVID-19 economic downturn, allowance prices in the K-ETS climbed to EUR 30 in the face of a thin market dominated by compliance-focussed trading and limited opportunities for price discovery. Such a relatively high price level presented opportunities for emissions abatement although there are indications that market distortions may have led the price signal to deviate from MAC.

In an undistorted market, the ETS sends a price signal that reflects the MAC of the covered sectors and businesses by incentivising regulated entities to buy permits when the allowance price is below their (firm or facility level) MAC, and to sell permits when the allowance price is above MAC and abatement activities are cost efficient. In this way, the market ensures that the emissions target —set by the cap— is achieved at minimal cost.

Mapped out in detail in our conceptual study (Acworth et al., 2019), design elements of the ETS, sectoral market regulations, and market structures can impact the price signal in such a way that the allowance price may deviate from the system's MAC. Conversely, electricity sector regulations and market design impact the reflection of MAC by determining the level of carbon cost pass-through along the supply chain as well as setting incentives for short- and long-term abatement opportunities (e.g. efficiency standards, renewable support schemes). Supply-demand dynamics in energy markets furthermore play into the electricity sector's MAC by setting fuel costs, which may alter the fuel switching potential for a given allowance price.

Figure 1 and Figure 2 show that emissions of sectors covered in the K-ETS have moderately increased since 2015, by an annual growth rate of 2.6% over 2015-2018. *Ex-post* allocation changes in Phase 1 (early reduction credits, new entrants, and allocation adjustments) ensured an overall modest surplus of allowances in the system's early years. The market went short by a small margin starting in 2018—approximately 8MtCO_2, or 1.3% of the cap—which was offset by carry-over banking of 37.7Mt from Phase 1. Nonetheless, KAU prices steeply increased from Q3 of 2018 onwards (see section 3.1, Figure 2).

Low market engagement and risk-averse behaviour, constraints on market participation, cost compensation measures, and allocation provisions have likely caused market distortions that have affected the price signal's reflection of MAC.

Market engagement

Phase 1 of the K-ETS was characterised by some degree of political uncertainty when legal complaints over allocation levels, lack of long-term targets, and institutional restructuring led to concerns about the system's longevity, rendering participants reluctant to trade. With these issues resolved, the MoE consolidated the K-ETS's role as the overall policy tool for achieving Korea's climate targets, substantially decreasing market uncertainty. This is reflected by increasing buy-in among regulated entities. In the GIR's stakeholder survey held after the first trading year of Phase 2, overall satisfaction with the ETS in Phase 2 rose to 53% — a near doubling compared to previous years (GIR 2019; 2020a).

While there is much greater clarity on the long-term direction of the system, some degree of uncertainty remains as regards the more detailed ETS provisions, mainly resulting from relatively frequent changes to flexibility provisions for market stability purposes and contention surrounding the stringency of allocation benchmarks. This may have led some companies to adopt a more cautious approach, delaying engagement with the market. Furthermore, low support for the system by a remaining group of participants corresponds with a low eagerness to participate in the allowance market. In the GIR's stakeholder survey on Phase 2, only 8% of respondents indicated a willingness to make a profit from emissions trading, whereas the rest preferred to keep trading at a minimum (GIR, 2020a). This also finds support in an earlier study by Suk, Lee, and Jeong (2018) who find that certain firms perceive the ETS as a compliance mechanism rather than a market on which to trade assets that have an underlying financial value.

Active trading in the K-ETS has been limited to a small group of firms, mainly electricity generators that account for most demand and tend to have more trading experience. In the first trading phases, 3% of participants accounted for 55% of total trading volume (MoEF, MoE 2019). High market concentration can have a considerable impact on the quality of the price signal as participants less responsive to market signals may forego trades that could improve the overall cost efficiency of abatement. A higher risk premium on trading by less active market participants is then reflected by a status quo bias and endowment effects (Ahn 2019).

Banking, borrowing and market constraints

Under these market conditions, there is reason to assume that entities with surplus in the K-ETS have been more inclined to bank allowances for future compliance or borrow from future allocations, rather than engage in market transactions. These dynamics likely changed with the onset of emissions reductions induced by COVID-19, reflected by an increasing KAU19 supply over summer 2020 and expectations of decreasing allowance prices (KRX, 2020). In anticipation of growing surpluses, entities facing a shortage have had a higher incentive to borrow allowances.

In a liquid market, banking and borrowing can temper price shocks between trading years and improve the cost effectiveness of abatement by facilitating the inclusion of intertemporal factors in businesses' investment planning (Brunner et al. 2009). In a liquidity constrained market with no third-party participation, there are indications that the effect can be more cyclical in nature. The government has effectively targeted this issue in more recent years by linking banking and borrowing limits to an entity's trade activity (section 2.2.3).

Etienne and Yu (2017) note that market participation was decided to be limited out of concerns for excessive liquidity and potential price bubbles. Nonetheless, low liquidity and scarcity on the secondary market likely contributed to the rising price environment until May 2020. In the low-price environment in the final year of Phase 2, liquidity remains a key concern. In Acworth et al. (2019) we state that third-party participation can have ambiguous effects on the price signal as financial trading strategies may deviate from regulated entities' marginal abatement costs. In the case of the K-ETS, we expect the opening of the secondary market to non-compliance entities in Phase 3 to bring the price signal more in line with MAC. Financial participation in the market will improve market liquidity, tackle the concentration of sellers in the market and reduce transaction costs by enabling industries less familiar with spot trading to outsource their trading strategies. Most experts interviewed for this study underline the role of third-party participation in activating the market.

Market regulations

Price developments in the K-ETS are to large extent shaped by the electricity sector, which has been a net-buyer accounting for 44% of ETS emissions in 2018 and 60% of allowance demand (GIR, 2020a). Electricity sector regulations have affected the price signal's reflection of MAC due to the presence of a cost compensation mechanism for purchased allowances (analysed in depth in Chapter 5.2). Essentially, electricity producers have been compensated for net allowance costs and therefore are not penalised for unabated emissions. By subsidising demand, the mechanism has exerted upward pressure on KAU prices, placing a higher burden on industry sectors that have not been covered by similar compensation schemes. Due to the cost compensation mechanism, the price signal has not reflected MAC curves tied to the electricity sector, which is likely to have rendered abatement under the K-ETS more costly (also see Kim & Lim, 2020).

Allocation rules

The allocation methodology may have also distorted the reflection of the MAC in some cases. The number of allowances that entities receive through grandparenting is updated on a rolling basis. Updating allocation based on actual emissions can distort production and investment choices where entities can foresee or predict that changes in their activities will affect their future allocation (Acworth et al. 2019). While no empirical evidence was found to support this, updating allocation based on emissions has resulted in distortions in earlier phases of the EU ETS (for an overview see Acworth et al. 2020) and was raised as a concern for the K-ETS by some of the market experts interviewed for this study.

3.2.3 Long-term predictability

There are mixed signals on the long-term direction of the price signal in the K-ETS. Stricter rules for Phase 3 and the possibility of further climate policy reforms are likely to strengthen the price signal, whereas the effect of companion policies in the electricity sector through low-carbon capacity additions as well as regulatory reforms enabling cost pass-through may limit price increases through reduced allowance demand (via higher power sector abatement). The allowance price to date has reacted strongly to policy interventions. At the same time, enhanced price discovery in Phases 2 and 3 through increased auctions, expanded benchmark-based allocation (i.e. less free allowances) and third-party participation create more certainty and predictability regarding the allowance price level. Such foresight is key to facilitating low-carbon investments and ensuring project financing, notably in the electricity sector where abatement options are capital-intensive and require long-term certainty on cash flows in order to recover capital expenditures.

Predictability increases when there is credible information about the future allowance supply. In 2018 the MoE released the revised 2030 GHG reduction roadmap and tied the ETS cap to sectoral reduction targets. Exact cap levels, however, are only announced one year ahead of each trading phase by means of the Allocation Plan. Continuity and certainty on the market's parameters have improved following the extension of trading periods to five years starting in 2021. Experts note that price predictability would further improve if the government were to announce total annual allowance supply toward 2030 further in advance, for instance through an updated ten-year master plan.

Some level of uncertainty further exists surrounding the broader policy package for the low-carbon transition and its effect on allowance demand, such as the pace of the coal phase down and renewable capacity additions, and the future direction of electricity sector regulation—policies that can have a major impact on price developments in the K-ETS and which are described in more detail in Chapters 4 and 5.

A shifting political landscape following the landslide victory of the Democratic Party in parliamentary elections in May 2020 and the announcement in October the same year of a net-zero emissions target for 2050 will have a major impact on the policy package going forward. As for the K-ETS, steeper reduction targets for 2030 and beyond will be necessary and will likely be reflected in updated provisions for Phase 4 of the K-ETS. At the same time, there remains some uncertainty as to the medium-term implications for the K-ETS and whether further revisions within the third trading period can also be expected.

As described in Chapter 2.2.5, market stability provisions in the K-ETS are managed by the Allocation Committee, which based on predefined criteria, may intervene in the market by releasing allowances from the reserve, establish retention limits, adjust borrowing or offset limits, and set up a temporary price ceiling or price floor. Upper or lower bounds, whether quantity- or price-based, are not defined *ex ante* for the latter three measures leaving such interventions to the discretion of the Allocation Committee. This has to some effect offset improvements in price predictability that could otherwise have been attained. Interviewees observe that the Allocation Committee has had limited effect on the allowance market in the first two trading phases, mainly as it has only intervened twice (in 2016 and 2018). No interventions have been made in 2020 despite the sharp decline in prices. It has been suggested through the interviews that its effectiveness could be improved by revising the intervention criteria and defining clearer rules for intervention. This would help market participants predict how the Allocation Committee would respond to market shocks.

The MoE has signalled to introduce derivative trading in the K-ETS in the third trading phase (MoEF, MoE, 2019). Experts interviewed for this study indicate that the government will most likely adopt an incremental approach by which derivatives would be introduced after the effects of third-party participation in the market will have been analysed. Introduction of a futures market will bring about a forward curve that could improve price predictability by reducing market power and revealing information about participants' expected abatement cost next to making the system more responsive to economic cycles and shocks.

3.2.4 Environmental effectiveness

The environmental effectiveness of an ETS equals the amount of emissions abated, which in turn depends on the allowance supply set by the regulator, as well as the impact of different design provisions on the supply of allowances. The environmental effectiveness of the K-ETS has been ensured through consistent enforcement of rules surrounding the level of the cap.

First, despite pressure from industry stakeholders in the first trading phase to adjust the cap and increase allocation levels, the Korean ministries stuck to the previously agreed cap trajectory and as such managed to maintain the environmental integrity of the K-ETS (GIR, 2018). The ROK's adaption of long-term climate targets in 2018 (which are linked to the ETS), has helped consolidate the role of the system as one of the main tools to reduce emissions.

Moreover, strict eligibility criteria on the use of international credits have ensured that their impact on environmental effectiveness has remained limited, while the offsets that have been allowed have served as a reliable source of supply to the market. Although offsets continue to be allowed in Phase 3, interviewees point out that there is uncertainty surrounding their future rules. Domestic offsets are seen to add complexity due to the risk of double counting, while international credits do not contribute to domestic emission reductions. Prioritising domestic abatement and simplifying the policy mix are regarded as potential benefits of limiting the role of offsets going forward.

4 The Korean electricity market

4.1 Electricity market design

The Korean electricity sector is characterised by a hybrid wholesale market design with a single buyer and a vertically integrated transmission, distribution, and retail structure. In the late 1990s the Korean government planned to follow the prevailing trend among developed nations of liberalising their electricity sector. The process of unbundling was planned in three steps. First, generation would be divested to allow the entry of new market players and create a competitive wholesale market. Second, the transmission and distribution segment would be restructured, with the liberalisation of retail markets to follow as the third step (Lee 2011).

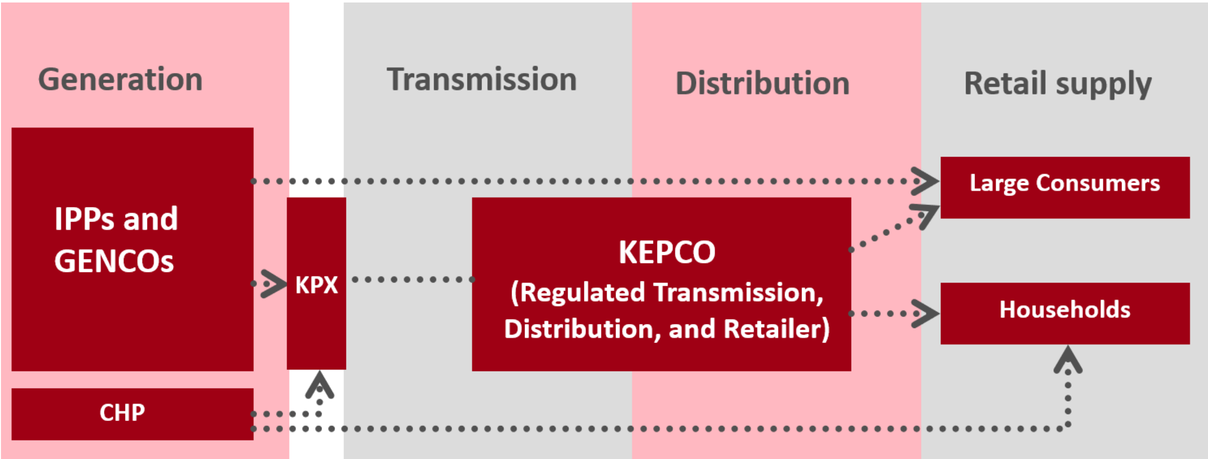
To this end, the Korea Power Exchange (KPX) was established in 2001 becoming the designated market and system operator, a day-ahead market was created, and KEPCO's generation assets were unbundled into regional generation companies (GENCOs) operating alongside independent power producers (IPPs). The aim was to encourage competition among the newly established GENCOs with privatisation plans envisaged at a later point.

The attempt to privatise the first GENCO resulted in widespread strikes, putting into question the proposed privatisation efforts (Lee, 2011). At the time, the notion of a competitive power market was not as widespread, drawing a general sceptical attitude from the public. Then, with the arrival of a new president and resistance from the labour unions, the reform was halted entirely. The GENCOs are still wholly owned subsidiaries of KEPCO, though with independent business and administration structures. KEPCO serves as the single buyer of electricity from the KPX and has retained a monopoly in the transmission, distribution, and retail segments (Figure 4). In each of these domains, KEPCO is subject to independent evaluation and price setting constraints explained further below.

Figure 4: Overview of KEPCO's role in the electricity sector

Source: KECPO website available here.

Figure 5: Korean electricity market structure



Source: Authors' elaboration.

Today, the Korean electricity market is characterised by limited wholesale competition, operated by the KPX and overseen by MOTIE. A simplified depiction of the market structure is shown in Figure 5.

Prior to the establishment of the KPX, independent power producers (IPPs) were allowed power purchase agreements (PPAs) with KEPCO but now participate on the wholesale market together with state-owned GENCOs and many smaller renewable energy (RE) producers. There are still some existing PPAs, though the amount of electricity procured through such contracts has shrunk from its peak of close to 5 TWh in 2003 to under 1 TWh (i.e., 0.18% of total electricity generation) in 2018.[17]

The KPX operates the wholesale market and is responsible for grid management and real-time dispatch of generation sources. Like KEPCO, which is responsible for ensuring reliable grid access and network codes, it is under the control of MOTIE. The KPX has around 20 conventional technology IPPs listed as their members (generation companies) as well as several thousand RE generators[18] (KPX, 2020; Table 7). Some of the RE producers are also owned in part by KEPCO. The KPX has several internal committees and councils dedicated to tasks ranging from dispute settlement to rule revision and cost evaluation.

Korea introduced a cost-based pool (CBP) market as part of the reforms in 2001. Under this system, wholesale electricity costs per technology are determined by the regulator (the cost evaluation committee) on a monthly basis, where daily prices are set through a price setting schedule following least-cost dispatch, and capacity payments remunerate fixed costs (KPX, 2015). These price mechanisms are explained in Chapter 4.3.

Plans for the further liberalisation of the Korean electricity market were halted at the unbundling of KEPCO in 2001 due to political challenges associated with potential increases in the electricity price. In recent years, these discussions have revived with MOTIE planning on developing a competitive wholesale market through the introduction of intraday trading in a price-based pool which would replace the cost-based pool market (Jeong 2020).[19]

[17] Based on data from the Korean Electric Power Statistics Information System

[18] RE Generators over 1 MW need to be listed on the exchange to sell their energy.

[19] The CBP and PBP are variations of the power pool model where electricity sources are centrally dispatched by the system operator, accounting for technical and system constraints. In a CBP market, variable costs are determined administratively, often through fuel-technology benchmarks, while price setting is decentralized in a PBP market enabling participants to bid according to

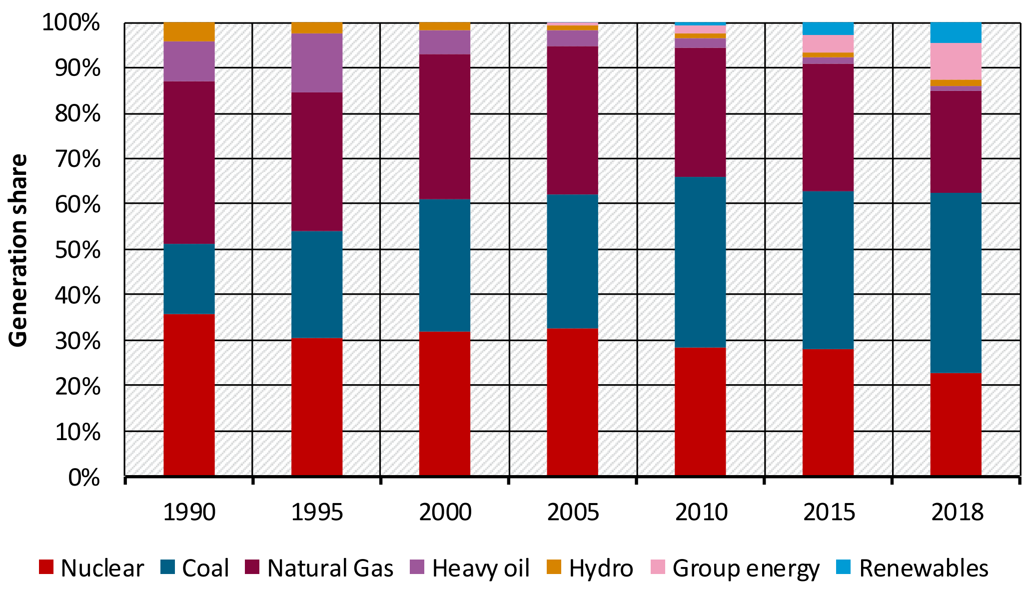
4.2 Market structure and dynamics

4.2.1 Electricity mix and age of generation assets

Prior to 1990, ROK's electricity mix was almost 50% nuclear. However, since the mid-1990s, the Korean electricity mix has increasingly diversified with additional supply from coal, natural gas, and in recent years also renewables. The 6th Basic Plan for Long-term Electricity Supply and Demand (BPLE), published in 2013, was indicative of the prevalence and preference for expanded coal capacity, coming at a time of steadily rising demand and shortly after the Fukushima Daiichi nuclear disaster. Of new capacity to be added in the 14 years looking ahead, just under half (10.5 GW of a planned 23 GW) was to come from coal (MOTIE, 2013).

As shown in Figure 6 and Figure 7, the share of coal-fired power has increased significantly in the past few decades, as has installed gas capacity. Renewable energy has also made substantial inroads since 2010, albeit from a small starting point. In the figures below, "Group energy" describes district heating and electricity and consists mostly of gas units. In the data available, it was distinctly delineated from the other sources and as such is reflected here.

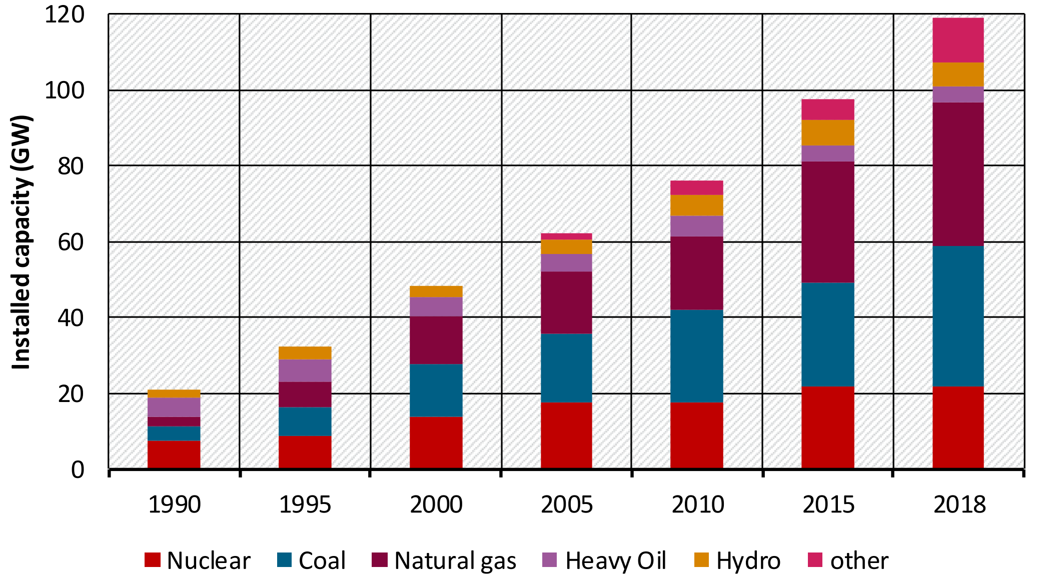
Figure 6: Relative generation share by technology 1990-2018



Source: Authors' elaboration based on data from EPSIS (2019).

their individual cost profiles. Advanced systems may adopt a two-sided pool where large consumers can directly participate in wholesale markets. These differ from self-dispatch systems where bilateral trading is more prominent. Variations across these models and hybrid designs exist and are often adopted as well (e.g. see, Barroso et al. 2005; IRENA 2017).

Figure 7: Installed capacity by technology 1990-2018*



Source: Authors' elaboration based on data from EPSIS (2019).

*Specifics on installed renewables were not available from this source but are grouped under other.

Since the election of Moon Jae-In as president in 2017, the outlook has changed as best exemplified by the marked shift in the planned capacity additions in the 8th BPLE and 9th BPLE as well as the overall language characterising the electricity mix. Published in 2017, the 8th BPLE highlighted how Korea was further behind the OECD average when it came to renewable energy production and capacity and explicitly stated the intention to reduce the role of both nuclear and coal in the power mix (MOTIE, 2017). Plans to phase down coal include a halt to new investments and a lifecycle cap of 30 years. The Third Energy Master Plan released in 2019 did not explicitly address the status of seven coal plants under construction, which were later confirmed to be completed and will come online on a rolling basis over the incoming years. Despite incremental capacity additions, the 9th BPLE, released in 2020, stipulates steeper reductions in coal alongside increases in gas and renewables—earmarking 30 coal plants to be decommissioned or retrofitted to gas by 2034 (section 4.4; MOTIE 2020).

Table 5 below provides an overview of the age of the Korean electricity generation fleet. Heavy oil plants are on average nearing the end of their technology lifecycles. On average coal plants are around 16 years old. The coal fleet should in the next few years become 'younger' and more efficient, as coal plants reaching 30 years of operation will be decommissioned or converted to gas, and the construction of several new plants are finalised.[20] In the long term, the age of the fleet will gradually converge towards 30 years as older units are taken offline and no new coal capacity is added to the grid.

[20] The conversion efficiency of Korea's coal fleet has ranged between 35-38% since 2004. Calculated by dividing energy output by total energy input. For electric power measured in current and voltage. Thermal power plant efficiency available on the EPSIS website: http://epsis.kpx.or.kr/epsisnew/selectEkgeTepGrid.do?menuId=040400

Table 5: Age of fleet – conventional technologies*

Technology	Weighted** average age of fleet 2019 (years)	Average Technology Lifetime (years)
Coal (Bituminous)	16	30***
Heavy Oil	40	60****
Gas	15	25
Nuclear	21	40

* Public information available only for GENCOs
** Weight calculated based on installed capacity
*** Though coal plants can run longer (especially with retrofitting), the President Moon Jae-in has pledged to close coal plants older than 30 years during his presidency (Climate Analytics 2020).
**** Or more – only used in peak demand hours

Source: Authors' elaboration based on statistics made available by the Korea Power Exchange and commissioning date taken from the Global Energy Observatory

The role of nuclear in the capacity mix is also set to decrease towards 2034 as no lifetime extensions will be granted and investment in new capacity is halted (Table 6; MOTIE 2020b). Nonetheless, both coal and nuclear will remain important sources for baseload electricity supply going forward. As depicted in the table below, the government plans to offset reduced coal and nuclear with gas-fired power and renewable sources, the latter constituting the bulk of new investments to meet long-term demand growth (section 4.2.3). Under current policies, more than 60 GW of renewable capacity will be added to the grid by 2034.

Table 6: Projected installed capacity by generation source (9th BPLE)

Technology (GW, %)*	2019	2030	2034
Nuclear	**23.3** (19%)	**20.4** (12%)	**19.4** (10%)
Coal	**37.0** (30%)	**32.6** (19%)	**29.0** (15%)
LNG	**40.0** (32%)	**55.5** (32%)	**59.0** (31%)
Renewable	**15.8** (13%)	**58.0** (34%)	**77.8** (40%)
Pumped hydro	**4.7** (4%)	**5.2** (3%)	**6.5** (3%)
Other	**5.0** (4%)	**1.2** (1%)	**1.2** (1%)
Total	***125.3***	***173.0***	***193.0***

* Numbers are rounded and may therefore not add up to the decimal of total capacity.

Source: MOTIE, 2020b

The Korea Renewable Energy 3020 Plan foresees 33 GW renewable capacity towards 2030 to come from solar photovoltaics (PV) and the remainder from wind power. Through these planned capacity additions, MOTIE (2020b) projects electricity generation from renewable sources to increase from 6.5% in 2019, to 20.8% by 2030 and 26.3% by 2034. In parallel, the share of coal will decrease from 40.4% in 2019 to 34.2% by 2030 in the reference scenario, or 29.9% in the target scenario (through additional measures limiting utilization rates). Nuclear and gas-fired generation shares will both decrease slightly from 25.9% and 25.6% in 2019 respectively. With the Korea Green New Deal, and the establishment of a 2050 net zero target, climate policy is firmly on the administration's agenda, which aims to have 42.7 GW of VRE installed by as early as 2025 (MoE, 2020c). Even steeper increases are not excluded given the introduction of an economy-wide net-zero emissions target.

4.2.2 Ownership and market concentration

KEPCO owns 100% of the shares of its six subsidiary GENCOs (five thermal and one nuclear/hydro) (KEPCO, 2017), which are in turn majority controlled by the Korean government (18.2% through direct government ownership and 32.9% through the Korean Development Bank (which itself is wholly owned by the government)) (KEPCO, 2013). In addition to conventional generation, each GENCO also has its own renewable energy assets.[21]

The proportion of IPPs has increased to almost 30% of electricity production since the first deregulatory moves 20 years ago (Lexology, 2018). Government regulation surrounding investment has resulted in relatively high barriers to market entry slowing down the IPPs' growing market share (see section 4.4 for further details).

Table 7 below shows the current breakdown of membership (December 2019). The KPX differentiates between RE and non-RE producers. RE installations with over 1 MW of capacity are required to sell their electricity on the KPX (under 1 MW they can trade directly with KEPCO).[22] Many of the RE installations are owned wholly or in part by either the GENCOs or the IPPs as part of their portfolios to meet the shares necessitated under the RPS. The number of IPPs and their respective capacity has increased significantly since 2015 when their membership counted only seven and their capacity about 25% of the level it was in 2019.[23] The amount of RE companies participating in the KPX has grown ten-fold in this period. Despite the growth in IPPs, the Korean electricity market remains dominated by the six GENCOs which retain an overall capacity share of 71%.

Table 7: Number of members of the KPX and their combined MW capacity per power source

	Type of producer	Capacity (MW)	Number of members on the KPX	Share of overall capacity
Conventional Technology	GENCOs	83,535	6	71%
	IPPs	21,199	20	18%
	Group Energy	6,914	29	6%
	Other	53	5	0%
	Total Non-RE	**111,701**	**60**	**95.5%**
Renewable Energy	Wind	1,381	67	1%
	Solar	3,184	3,297	3%
	Small Hydro	77	22	0%
	Waste	151	41	0%

[21] An overview of the RE assets of the individual GENCOs can be found here: Korean South-East Power Co., Korea Western Power Co., Korea Hydro and Nuclear Power Co., Korea Midland Power Co., Korean Southern Power Co., Korea East-West Power Co.

[22] https://www.kpx.or.kr/eng/contents.do?key=300

[23] The differences can be gleaned from the updated Korean page (December 2019) and the English language page last updated in 2015.

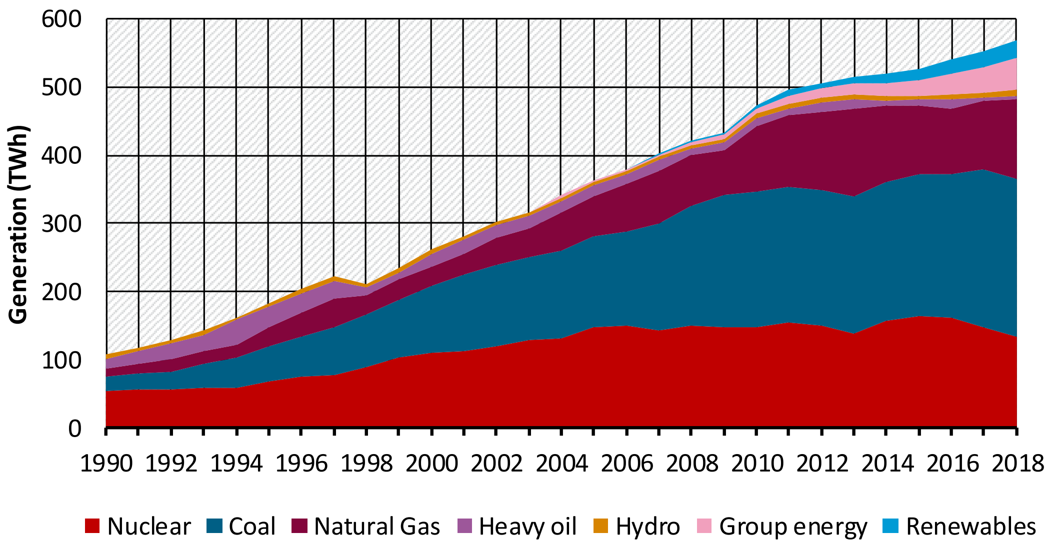
	Type of producer	Capacity (MW)	Number of members on the KPX	Share of overall capacity
	Biomass/Biogas	226	39	0%
	Fuel Cell	214	15	0%
	Total RE	**5,233**	**3,481**	**4.5%**
	Total	**116,934**	**3541**	**100%**

Source: Authors' elaboration based on membership and capacity numbers available at the KPX.

4.2.3 Electricity generation and demand

Electricity demand has been growing rapidly in Korea over the last 30 years from just over 100 TWh in 1990 to over 500 TWh in 2018.[24]

Figure 8: Yearly generation by technology (TWh) 1990-2018*



Source: Authors' elaboration based on data from EPSIS (2019).

*Graph represents only utility generation. Generation for companies through PPA generation was not available by power source —its share in total electricity generation is marginal.

The table below adapted from the 9th BPLE shows the projected growth in both consumption and peak demand. Looking ahead, electricity demand is expected to grow by an annual average rate of 1.6% towards 2034. Peak demand shows the maximum yearly peak, which has historically occurred in winter, and is expected to increase by 1.8% over the same period. Both growth projections are slightly lower compared to the 8th BPLE. The numbers in Table 8 indicate a growth rate in a reference scenario, i.e., without policy intervention. Under the target scenario, which considers demand-side management, the growth rates are 0.6% and 1.1% respectively.

[24] For comparison, Germany, which at present has a similar load profile, has grown from around 550 TWh to just 600 TWh in the same time period (IEA, 2020).

Table 8: Projected consumption and demand growth 2020-2034

Year	Electricity Consumption (TWh)	Peak Demand (GW)
2020	516.7	91.7
2021	532.9	95.2
2022	544.6	97.4
2023	556.2	99.6
2024	567.8	101.5
2025	577.4	103.4
2026	587.2	105.2
2027	596.1	107
2028	604.5	108.6
2029	612.5	110.2
2030	620.2	111.8
2031	627.7	113.3
2032	634.7	114.7
2033	641.6	116.1
2034	647.9	117.5

Source: MOTIE, 2020b

Demand-side management (DSM) strategies feature prominently in Korea's electricity strategy to reduce peak demand. Earlier methods of DSM have included energy efficiency incentives and initiatives, audits and smart metering of factory electricity usage, and an extension of smart metering to private homes. Moving forward, DSM will be extended through an expansion of household solar PV and an expansion of the Demand Response Market, where customers can sell their reduced demand (Ko et al., 2020). The extent to which demand will continue to grow will depend, *inter alia,* on the success of the deployed DSM strategies, which are discussed in further detail in Chapter 4.4.2.5.

4.2.4 Cross-border electricity trade

Cross-border electricity trade could facilitate the implementation of Korea's energy objectives through improving security of supply, ensuring more efficient capacity usage, and facilitating the integration of increased renewable capacity by lowering the risk of curtailment.

Improving regional interconnection capacity is complicated by Korea's geography. As its only contiguity is with North Korea, ROK is essentially an electrical island. There are currently no interconnections with geographic neighbours such as Japan, China, Russia, and Mongolia, although there is experience with interconnectors with two high-voltage direct current lines running to Korea's southern island of Jeju. In an effort to improve the region's electricity reliability following the 2011 Fukushima Daiichi disaster, an initiative was established to facilitate cross-border electricity trade. The plan, called the Super Grid in Northeast Asia, envisages high voltage lines to transport electricity from RE sources from regions with particularly good conditions (such as wind regions in central and east China and photovoltaic in the Gobi Desert) to load centres on the eastern Asian seaboard. The project is still in its early stages, with the South Korean government aiming to have the research and evaluation for a possible connection with Russia completed by 2022 (MOTIE, 2017, p. 61).

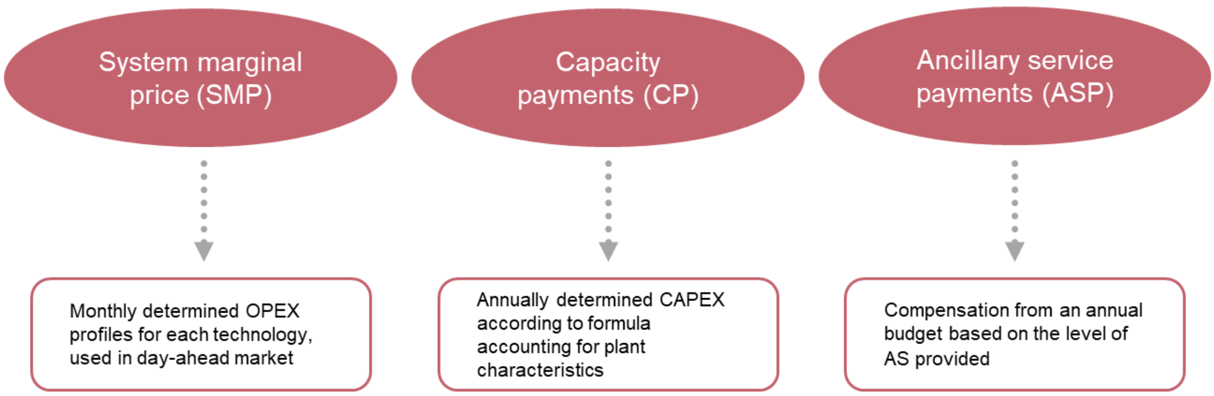
The initiative, which is led by the Renewable Energy Institute, recently released a report evaluating the costs of possible interconnectors linking the port city of Busan with three different possible destinations in Japan. The lines would have a minimum capacity of 1 GW and a maximum capacity of 2 GW. Overall, if a grid-fee model is used to recuperate investments costs, the interconnector is found to marginally increase the electricity prices by 1,114 KRW/KWh (EUR 0.86/MWh) (Kimura and Ichimura, 2019, p. 28-29). Interconnectors serve to provide efficiency across the systems, as electricity will flow from the system with the lower prices to the system with the higher prices, bringing down overall system costs. Currently, wholesale prices in Japan are on average higher than in Korea, implying that under market conditions, Korea would be a net exporter of electricity (Renewable Energy Institute 2018). If the interconnectors to the west were to be realised, Korea would further benefit from increased security of supply (Chung et al., 2017). All plans for future interconnectors are still in very early stages but have received interest and support from relevant regional actors.

4.3 Wholesale pricing and dispatch

4.3.1 Pricing structure

The wholesale market price is mainly determined through two separate payments: the SMP and the capacity payment (CP). In principle, the SMP covers the operating costs (OPEX) of power stations. The CP remunerates power plants for their availability to produce and is supposed to enable power producers to recover their investment costs (CAPEX), also on a regulated basis (see section Companion policies and drivers of investment4.4.2). Conventional generators furthermore receive compensation for grid stability services through an Ancillary Service Payments (ASP) scheme.

Figure 9: Wholesale electricity pricing in Korea



Source: Own creation.

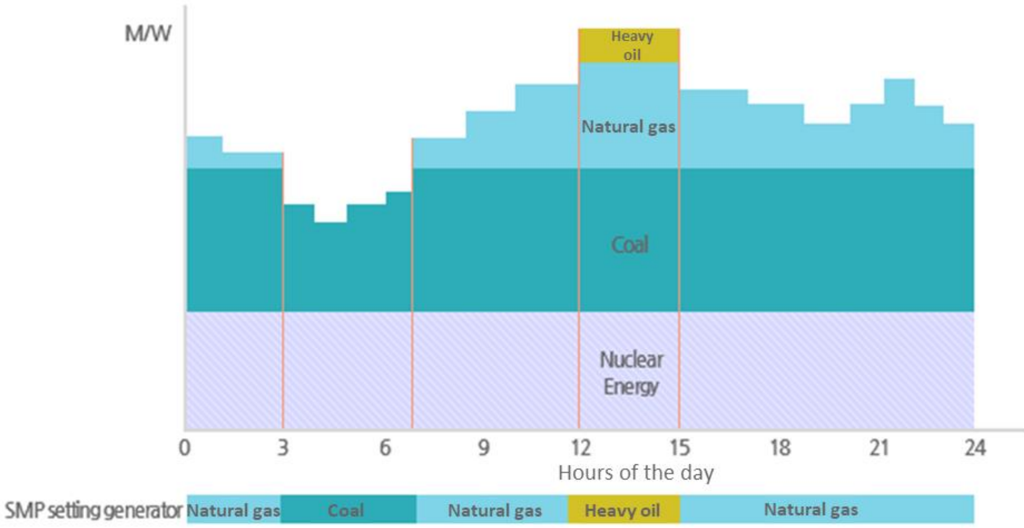
This payment structure, further detailed below, might change from 2025 onwards. The government plans to replace the cost-based pool (CBP), based on predetermined technology-specific prices, with a price-based pool (PBP) accompanied with intraday and real-time markets (Jeong, 2020). The introduction of a PBP market would have major implications for the electricity sector and the impact of the K-ETS (Section 5.2.3). Market criteria and regulations are currently under discussion (MOTIE 2020b).

4.3.2 The System Marginal Price

Under the current (one-sided) CBP market, generators bid capacity for the next day to the market operator, the KPX, according to predetermined prices per fuel source. The Generation Cost Assessment Committee (GCAC)—a sub-group of the Electricity Market Operation Council—determines OPEX profiles reflecting the average efficiency for each generation technology. To this end, power producers are required to submit monthly generation cost data.

The variable costs are then used by generators to offer price-quantity pairs on the day-ahead market. The KPX forecasts demand and ranks the capacity bids in in ascending order of price until demand is met. This is done through the Price Setting Schedule (PSS) which determines optimal production costs accounting for hourly demand, start-up and ramping costs and incremental fuel costs. Congestion and generation constraints are not considered in this process. Generators can place bids until 10AM D-1, the dispatch schedule is finalised at 3PM one day ahead of delivery (EMSC & KPX 2019).

Figure 10: System Marginal Price KPX



Source: Adapted from KPX 2020

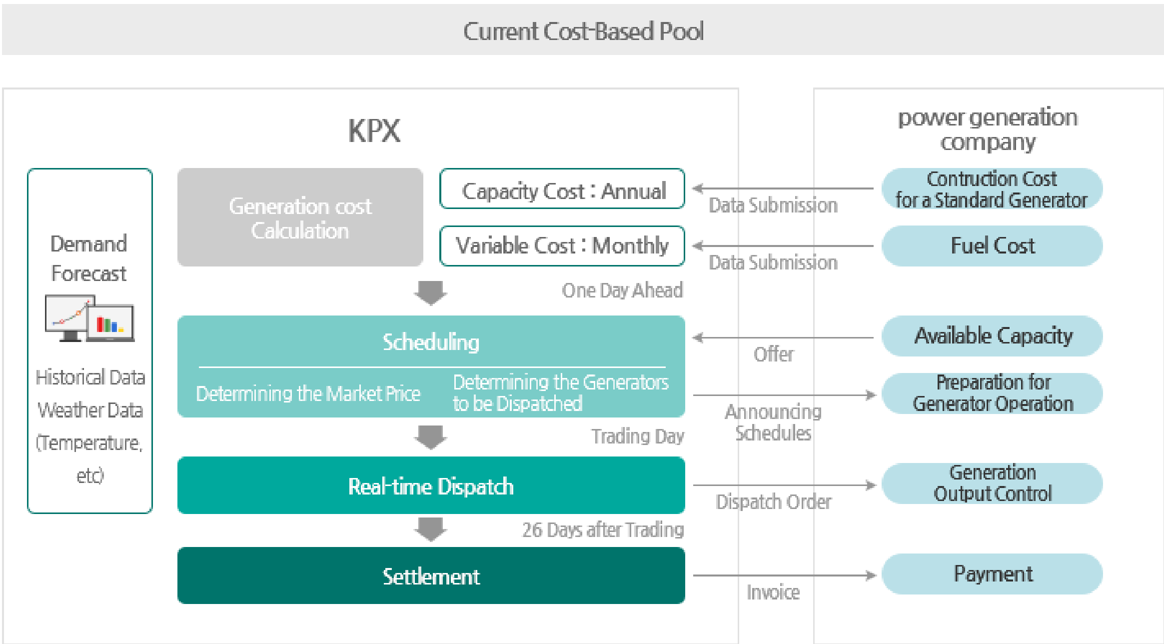
The SMP is formed on a marginal basis. The most expensive unit of production needed to meet demand determines the "equilibrium" SMP price. The difference between a power plant's variable costs and the market clearing price determines return margins.[25] So far, this arrangement has mainly benefited coal-fired and nuclear power plants, given their lower OPEX in comparison to LNG. To ensure fair returns across generation units, market settlement rules such as adjustment factors apply (Lee et al. 2013). First introduced in 2008, the settlement adjustment factors were revised in 2014-15 to better accommodate LNG-fired power plants.

While underlying operational (mainly fuel) costs are administratively set on a monthly basis, the SMP varies for each hour of the (next) day in line with supply-demand dynamics. Figure 10 depicts the load pattern on a 24-hour cycle and the different generation technologies that are called on to meet demand. Open-cycle gas units are the marginal unit, and hence often price

[25] The final price calculation is as follows: "The price a generator ultimately receives is the sum of his variable cost and a percentage of the difference between the SMP and his variable cost: P = MC + k (SMP-MC), where k is the so-called SMP adjustment coefficient and is set between [0.5 and 1]." (Vivid Economics, 2011: 13).

setters in the market. Given the pre-set OPEX profiles, price volatility under a CBP is limited. However, generators can hedge price risk through Contracts for Differences (CfD) (EMSC & KPX 2019). The system operator settles the discrepancy between generators' bids in the day-ahead market and real-time system dispatch operation through ex-post settlement and metering accounting for actual production and system constraints in the form of uplift payments. Lack of reflection of system constraints in the SMP, and an increasing gap between day-ahead and real-time dispatch (i.e., between market and system operation) have been a cause of concern, propelling the need for the introduction a real-time market (Park 2019).

Figure 11: Korean electricity market planning and procurement process



Source: KPX

4.3.3 Ancillary Service Payments (ASPs)

The KPX operates three reserves to balance electricity supply and demand on a real-time basis and ensure grid stability services can be called upon (Lee 2020).[26]

- Primary reserve power (frequency control): Generators can be called upon within 10 seconds to operate for ≥ 5 minutes
- Secondary reserve (operational reserve): Generators can be called upon within 5 minutes to operate for ≥ 30 minutes
- Third reserve: Generators with a minimum of 20 MW capacity can be called upon within 30 minutes

Electricity generators wanting to provide ancillary services must submit detailed data of their generation plant's characteristics. And are remunerated from a fixed annual budget according to the level of services provided. This system might be replaced with market-based procurement, along with the introduction of a price-based pool market, to improve the efficiency of system balancing. It is reported that the share of ASPs as part of total settlement costs has declined, despite the need for grid stability services increasing (Lee 2018). This may reflect flexibility

[26] Such as voltage control, reactive power, frequency control, spinning reserves, and black start capacity.

services not being explicitly priced in the current market design, made up for through settlement adjustment factors and capacity payments that ensure flexible generation sources can recoup costs.

4.3.4 Capacity Remuneration

Power generators in Korea are remunerated for their availability to produce electricity, in addition to the rate they receive for electricity output (SMP). The creation of an additional revenue stream, in addition to the "energy only" CBP market, was considered necessary to compensate power stations that did not produce sufficient electricity and ensure their financial viability.[27] In particular, LNG-fired power plants are not dispatched at full capacity, as a result of their higher operating costs and thus lower rank in the merit order in comparison to coal-fired power plants. According to electricity market reform theory, higher prices on the intraday markets during times of scarcity can provide flexible producers with higher margins to recoup sunk costs (Léautier, 2019). In Korea, predetermined prices reflected by the SMP and the absence of intraday trading hinders producers from reacting to short term market dynamics, such as scarcity. The capacity payment (CP) responds to this "missing money" problem by guaranteeing power stations a minimum level of remuneration, independent of their actual output, based on fixed costs.

The CP was initially introduced to ensure the financial viability of LNG plants that were dispatched less often because of their higher OPEX profile. However, increasingly, the CP is now used in pursuit of the government's environmental objectives in the electricity sector and has become part of the regulatory and economic instruments used to steer the Korean electricity sector towards a low-carbon system.

The CP is determined annually by the GCAC for each type of generation technology (LNG, coal, nuclear, etc.) and factors in the age of the power station, energy efficiency and environmental performance, and its location. Power plants with lower GHG emissions and fine dust levels will thus benefit from higher remuneration (MOTIE, 2017, p. 43). The formula is as follows:

CP = Reference Capacity Price * Capacity Price Factor * Capacity Factor over time * Fuel Switching Factor (FSF)

The Reference Capacity Price considers technical characteristics based on year of entry into the market. The Capacity Price Factor considers a regional price signal that aims to reward the construction of energy producing facilities closer to consumption areas as to facilitate the integration of distributed energy sources and minimise grid costs.[28]

The fuel switching factor aims to remunerate the use of environmentally friendly energy. The fuel switching factor has ranged from 0.939 for the most inefficient coal plants to 1.0311 for the most efficient LNG plants (Seoul National University Nuclear Policy Centre (SNEPC), 2018). The CP is calculated in KRW/kWh. The capacity payments ranged between 8.92 KRW/kWh–9.74 KRW/kWh between 2004-2015 and are based on theoretic optimal capacity utilisation rates independent of actual output produced (ibid).

4.3.5 CHP pricing and dispatch

CHP installations accounted for 26% of total electricity generation from July 2019 to June 2020 (KESIS, 2020). CHP plants participate in the electricity market and next to receiving

[27] Indicated by experts interviewed for this case study.

[28] The ROK aims to increase the share of distributed energy resources from 11.4% in 2020 to 12.5% in 2029 (MOTIE, 2017).

remuneration for electricity output sell heat at regulated prices. Experts interviewed for this publication have indicated that the latter cannot be set at more than 110% of the heat tariffs charged by the Korea District Heating Corporation, the main heat supplier of Korea delivering about 50% of centralised heat to Korean consumers. Heat tariffs must be reduced following the implementation of cost saving measures. This arrangement does not incentivise the realisation of energy efficiency and GHG emission reduction projects, as the benefit of lower energy use (and thus lower OPEX) will be neutralised by a reduction of the tariff (Oh, 2019).

Revenues from both electricity and heat sales contribute to recovering the common costs of the production of electricity and heat. To incentivise the use of CHP and benefit from the efficiency benefits offered by the use of heat (a by-product to electricity production), the government compensates the additional fuel costs (i.e., OPEX under SMP) relating to the use of CHP for heat supply (MOTIE, 2017, p. 50). Furthermore, CHP installations are compensated for being located closer to consumption areas (under the "location factor" of the CP, section 4.4.2).

4.4 Investment policies

4.4.1 Regulation of generation investments and disinvestments (closures)

The investment process in the Korean electricity sector is, to some extent, bottom up. Power producing companies formulate plans for developing electric installations and for electricity supply. However, there is strict control and guidance over the design, approval, and implementation of investments in power generation. First, plans for the establishment of electric installations and for the supply of electricity must be submitted for approval to MOTIE (Korean Electric Utility Act, 2000, art. 26). Second, all power plants in Korea require an operating permit. This mechanism enables the government to control investments in electricity production capacity. Operating permits are not granted if the proposed power plant is inconsistent with MOTIE's projected national electricity supply and demand plan (Bae & Lee, 2018). Power plant proposals must furthermore meet environmental standards and be in line with the national emission reduction targets (Korean Electric Utility Act, 2000; 2017, art. 3, para. 2; art. 25, para. 7). The lifecycle of coal plants has been capped at 30 years (section 4.4.2.2).

Other key government priorities steering power sector investments are local air quality targets (especially the reduction of fine dust), the promotion of renewable energy sources and the security of electricity supply. To ensure the secure functioning of the Korean electricity system, the government promotes investments in RE and LNG to replace reduced coal and nuclear power.

4.4.2 Companion policies and drivers of investment

The objective of Korean electricity policy, and of the energy transition in particular, is to achieve an "economically viable energy mix that is both safe and clean" (MOTIE, 2017, p. 15). Four aspects are key to this policy: phasing down the use of (1) coal and (2) nuclear energy and replacing these sources with an increased share of (3) RE sources and (4) LNG. In addition, Korea promotes the use of CHP and district heating.

These changes to the Korean electricity fuel mix will have an impact on Korea's efforts to reduce its GHG emissions. However, these energy objectives are not solely driven by considerations of climate change mitigation. Tackling the high density of fine dust particles in Korea has increasing priority for the government next to addressing the safety concerns associated with the operation of nuclear energy. The regulatory mechanisms used to promote RE, and reduce coal and nuclear energy, closely interact with the ETS and are analysed in further detail in Chapter 5.

4.4.2.1 Renewable energy promotion

To achieve the RE objective of 42.7 GW by 2025, 58 GW by 2030, and 78GW by 2034 (MoE, 2020c; MOTIE, 2020b), the government imposes an obligation on electricity producers (with assets > 500 MW) to source a certain percentage of their electricity from renewable sources. The Renewable Portfolio Standard (RPS) replaced the Korean Feed-in Tariff scheme in 2012,[29] and covered 22 entities in 2020. The RPS target was initially set to reach at least 10% by 2023 (IEA, 2019b), but has recently been adjusted to 2022 as part of the Green New Deal announced July 2020 (MoE, 2020c). Besides performance standards for utilities, subsidies aim to promote the use of RE sources by households and reduce electricity offtake from the distribution network.

Conventional electricity producers can achieve their RPS obligation by investing in RE assets or by buying Renewable Energy Certificates (RECs) from RE producers (Son et al., 2019). To help generators meet their RPS requirements and increase the attractiveness of RE investments, Korea has created a secondary REC market. An REC represents one MWh of electricity generated from renewable energy sources that are weighted according to environmental and technical characteristics (Stangarone 2020). By selling RECs, RE producers obtain additional revenues to their sale of electricity on the market. Kim (2020) finds that the RPS has contributed to increasing investments in wind and solar power investments, albeit limited by price volatility in the REC market. The government has introduced the option of long-term (20 year) contracts with a fixed REC price (and either fixed or floating SMP) to improve the bankability of RE projects and reduce risk for RE producers (Kim, 2017). The Korea Energy Agency facilitates such contracts between RE suppliers and conventional producers that need to meet their obligations under the RPS through competitive tenders which have increasingly become the instrument of choice for adding new capacity to the grid (KEA 2019). The government plans to increase RPS obligations in order to develop new offshore wind and floating solar PV projects.

Investments in RE sources are thus mainly driven by the necessity for energy generators to comply with their RPS obligations. The corresponding REC proceeds provide an additional income stream for RE producers, while the option of long-term contracts provides price certainty to investors. RE growth was a key driver of reduced power sector emissions in 2019 alongside lower coal-fired generation (MoE, 2020f). With increasing renewable capacity planned to be added to the grid, K-ETS and RE support policies will need to be aligned in order to ensure the effectiveness of the carbon price signal, an issue to which we return in Chapters 5 and 6.

[29] See e.g., Huh et al. (2015). Feed-in tariffs do apply for small-scale renewable deployment.

Table 9: Projected renewable capacity towards 2034

	2019	2030 (8th BPLE)	2030 (9th BPLE)	2034 (9th BPLE)
Capacity	15.8 GW	58.8 GW	58.0 GW	77.8 GW
Share	12.6%	33.7%	33.6%	40.3%

Source: MOTIE, 2017;2020b.

4.4.2.2 The phase down of coal-fired power generation

The MOTIE and the KPX are required to review the environmental impact and public safety of the electricity industry and prepare policies accordingly (Korean Electric Utility Act, 2000, art. 3). Air pollution caused by fine dust particles has become an increasingly sensitive environmental, social, political, and economic issue. The government aims to reduce PM2.5 emissions with 35.8% below 2014 levels by 2022, down to 17-18 ug/m^3 on average and 40 ug/m^3 for poor air quality days, through its "Comprehensive Plan on Fine dust Management" (MoE, 2020d). The government recently increased its long-term fine dust target for 2030 to 57.1% below 2019 levels (MOTIE 2020b). Reducing output from coal-fired power generation and increasing the coal fleet's overall energy efficiency will be key to achieving this target. To this end, the government aims to decommission aging coal generators, interrupt supply of certain plants and convert coal-fired power stations to LNG-fired facilities (ibid). Reduced coal output as a result of fine dust measures was a key driver of reduced power sector emissions in 2019, alongside increased RE generation (MoE, 2020f).

For existing installations, the government is reinforcing the emission standards of coal-fired power plants based on the Clean Air Conservation Act (Kim & Cho, 2020). Moreover, the operation of coal-fired power stations older than 30 years will be interrupted during spring (March–June), and the government can order limitations to the operation of these plants (up to 80% of their capacity) in case of excessive air pollution. Article 4.5 of the Korean Electricity Act delegates authority to the KPX to suspend production for environmental reasons. In accordance with the Special Act on Reduction and Management of Fine Dust (2019, no. 16303), the city and provincial governors can implement emergency reduction measures to reduce the concentration fine dust particles when it falls within the criteria prescribed by the Ordinance of the MoE for a predetermined period. The Minister of Environment may request the city or province governor to implement the emergency reduction measures when two or more cities or provinces call for such measures. Emergency measures include changes to the operating time and utilisation of power generation facilities, and the suspension of generation.

As part of a gradual phase-down plan, three coal plants were closed by 2017, and 24 additional facilities will be decommissioned by 2030, 18 of which are earmarked for conversion to LNG by 2030 (MOTIE, 2017; 2020). By 2034, six additional coal plants will have been converted to gas-fired assets. Besides mitigating local air pollution,[30] these measures have become indispensable to align with the ROK's climate ambitions and energy transition goals.

As discussed in Chapter 4.2.1, these measures are expected to reduce the share of coal-fired electricity generation. The Phase 3 Allocation Plan also mentions the potential introduction of a

[30] See e.g., Chung (2019).

cap on coal-fired electricity generation by 2023, though further details have not yet been released at the time of writing (MoE, 2020g).

Table 10: Projected coal capacity towards 2034

	2019	2030 (8th BPLE)	2030 (9th BPLE)	2034 (9th BPLE)
Capacity	37.0 GW	39.9 GW	32.6GW	29.0 GW
Share	29.5%	32.5%	18.9%	15.0%

Source: MOTIE, 2017; 2020b.

4.4.2.3 The phase down of nuclear power

The Korean government has pledged to more aggressively pursue a phase-down of nuclear power. This policy decision follows concerns over the safety of nuclear power plants after the 2011 accident in Fukushima (Chung & Kim, 2018). Earthquakes in Gyeongju in 2016 and Pohang in 2017 exacerbated these concerns (MOTIE, 2017, p. 12). The nuclear phase-down involves the cancellation of several planned projects and the decommissioning of several older plants (i.e., no extended lifetimes). Between 2023 and 2030, ten aging nuclear energy generators will be decommissioned while plans for constructing six additional nuclear plants have been cancelled (MOTIE, 2017, p. 35). Nuclear power, per projections, is set to peak in 2022 and decline thereafter, both in terms of effective capacity and overall share (MOTIE, 2020b). However, it will remain key to supply security for years to come, 17 units remaining in operation by 2034, down from 26 in 2022. The (modest) reduction in nuclear is offset by a planned increase in the share of RE and LNG.[31]

Table 11: Projected nuclear capacity towards 2034

	2019	2030 (8th BPLE)	2030 (9th BPLE)	2034 (9th BPLE)
Capacity	23.3 GW	20.4 GW	20.4 GW	19.4 GW
Share	18.5%	16.6%	11.8%	10.1%

Source: MOTIE, 2017; 2020b.

4.4.2.4 CHP Support policies

The government promotes gas-fired CHP both for its energy efficiency benefits and its contribution to distributed energy generation.[32] Under the wholesale electricity pricing system, CHP installations benefit from a higher locational factor in support for the production of energy closer to demand centres.

However, in practice, the district heating industry is not in a strong financial position in Korea. According to a 2019 analysis by Oh of the Korea Energy Economics Institute, "the district heating industry in South Korea continues to weaken and lose competitiveness … at least 50% of all district heating providers in Korea struggled with operating and net losses every year between 2012 and 2016" (Oh, 2019).

[31] For a critical analysis, see Hong & Brook (2018) and Park et al. (2016).

[32] Indicated by experts interviewed for this case study.

District heating providers' poor financial situation has been attributed to the revenues CHP installations receive under the SMP and artificially low heat tariffs. Increasing heat tariffs faces strong popular and political resistance. At the same time, international experience demonstrates that increasing heat tariffs can negatively impact the market share of district heating companies, by incentivising consumers to shift to individual gas boilers or electric heating (Boute, 2012). In Korea, district heating companies directly compete with urban gas suppliers. The latter are in a much stronger financial position, as the majority of them "enjoyed operating and net surpluses" over the 2012-2016 period (Oh, 2019). Competition between individual gas supply and district heating is relevant for the interactions with the ETS, as pass-through of the carbon cost to district heating prices could incentivise a shift to individual boilers and result in carbon leakage as the latter are not covered under the ETS (see Section 5.4.1).

4.4.2.5 Energy end-use efficiency and Demand Side Management (DSM)

Energy efficiency and DSM have become a priority of Korea's electricity policy that is aiming to decouple electricity consumption and peak demand from economic growth. The objective is to reduce consumption by 14.5% and peak load by 12.3% through DSM by 2030 (MOTIE, 2017, p. 18). This will require a shift from the prior focus on capital expansion in production and transportation capacity.

To achieve these targets, the government relies on traditional regulation (command and control) such as energy efficiency performance standards in industry, bans on inefficient equipment (e.g., certain refrigerators), and energy efficiency requirements for buildings. The regulation on energy efficiency performance also applies to the electricity system itself (e.g., in the form of efficiency standards, and requirements to replace outdated transformers). Furthermore, under the Energy Efficiency Resource Standards scheme, energy suppliers are required to disseminate energy-efficient devices to their consumers to achieve energy savings. KEPCO, the Korea Gas Corporation, and the Korea District Heating Corporation need to invest in energy efficiency projects to reduce the energy use of their consumers. The Energy Utilization Fund operated by the Korean Energy Agency partly helps finance investments in energy efficiency, e.g., through low interest loans.

Despite these measures, progress with energy end-use efficiency improvements remains limited. This is largely due to the low electricity price and the political sensitivity of increasing prices to cost recovery levels, e.g., including the carbon cost.

4.5 Retail market and consumer price regulation

In Korea, the retail electricity prices have been kept artificially low. In the last few years KEPCO, the sole retailer, has been reporting growing losses (Lee, 2019), as it could not recuperate all costs incurred including from the surcharge associated with the RPS scheme.[33]

Retail electricity prices are kept low considering high social and economic sensitivity surrounding electricity price increases.[34] The public in Korea tends to regard electricity as a public good (The Economist, 2019), rendering changes in electricity prices a sensitive political issue. The government also tends to keep electricity rates for the energy-intensive industries low as to not affect their competitiveness. The contentious nature of electricity price reform was further illustrated in 2020 when MOTIE threatened to withdraw the power sector from the K-ETS against the backdrop of discussions around power sector benchmarks for Phase 3 and the

[33] Indicated by experts interviewed for this case study

[34] On social justice in the Korean electricity sector, see e.g. Kim et al. (2019).

introduction of an environmental dispatch mechanism. This issue was eventually resolved, and a compromise reached, as reflected in the Phase 3 Allocation Plan.

A retail business license is required to operate as an electricity retailer. MOTIE is the authority responsible for issuing licenses, with KEPCO being the sole recipient of such a license. All rate setting done by KEPCO is subject to approval from MOTIE (Korean Electric Utility Act, 2000). The rate structure in Korea is divided by type of use, is seasonally dependent, comprised of a fixed and varying component, voltage differentiated, and income sensitive. KEPCO separates the rates into residential, general, educational, industrial, agricultural, street lighting, midnight power, electric vehicle, demand management optional (KEPCO, 2016). KEPCO buys electricity on the wholesale market at the SMP and resells it to end-consumers at the MOTIE-regulated retail prices.

Tariffs are income sensitive. Progressive block tariffs apply with three electricity consumption brackets (Table 12). The more one consumes, the more one pays proportionally. The pricing logic stems from one of distributional sensitivity. Smaller (presumably less affluent) households will inherently use less electricity and therefore be subject to a lower fixed and variable rate. The use of cross-subsidies has exposed KEPCO to financial losses that are partly compensated by the government, and by the GENCOs through adjustments made based on a coefficient applied to the SMP in order to share the financial gap between KEPCO and its producing subsidiaries (Kim et al., 2013; Sioshansi, 2013).[35]

Table 12: Monthly residential retail rates

		Fixed Rate (won/household)	Variable Rate (won/kWh)
1-200 kWh	Low voltage	910	93.3
	High voltage	730	78.3
201-400 kWh	Low voltage	1600	187.9
	High voltage	1260	147.3
>400 kWh	Low voltage	7300	280.6
	High voltage	6060	215.6

Source: Authors' elaboration based on KEPCO (2016).

Time-of-Use pricing applies to consumers in the general, industrial, and educational services aimed at reducing consumption of electricity in periods of scarcity with separate off-peak load, mid load and peak load rates (KEPCO 2016). However, retail prices are not sufficiently high and differentiated to reflect the real cost of production and scarcity. According to a 2019 analysis by Jeong and Park of the Korean Energy Economics Institute, "the trend of SMP by season and time of day shows the current Time-of-Use rate plan does not reflect costs of production correctly. In terms of electricity for industrial use, the price per kilowatt-hour during light load hours is KRW 53-69/kWh [EUR 0.041 – 0.053/kWh], while the generation cost (unit settlement price) is KRW 112/kWh [EUR 0.086/kWh] for LNG" (ibid).

Prosumerism is also possible in Korea, with net-metering being an attractive option for residential consumers with higher energy consumption. As the pricing scheme is progressive,

[35] See also Bae & Lee (2018) and Kim (2019), referring to the deteriorating business performance of KEPCO and its subsidiaries, as a result of the "difference between wholesale and retail prices" (or the "difficulty linking changes in the purchase price of electricity with electricity rates".

net-metering provides better incentives for households with high consumption as it is likelier that the levelised cost of electricity (LCOE) of their home RE production will be lower than the KEPCO fixed rate (Lee, 2017).

The government introduced a separate climate rate to the retail tariff scheme in 2021 to avoid a widening cost recovery gap from environmental costs. The rate consists of ETS and RPS charges (previously included in the main tariff) and a new cost component for surcharges associated with coal reduction policies such as fine dust regulations. It is debited to consumers on a volumetric basis and indicated separately on the electricity bill (KEPCO 2020). The rate started at 5.3 KRW per kilowatt-hour.

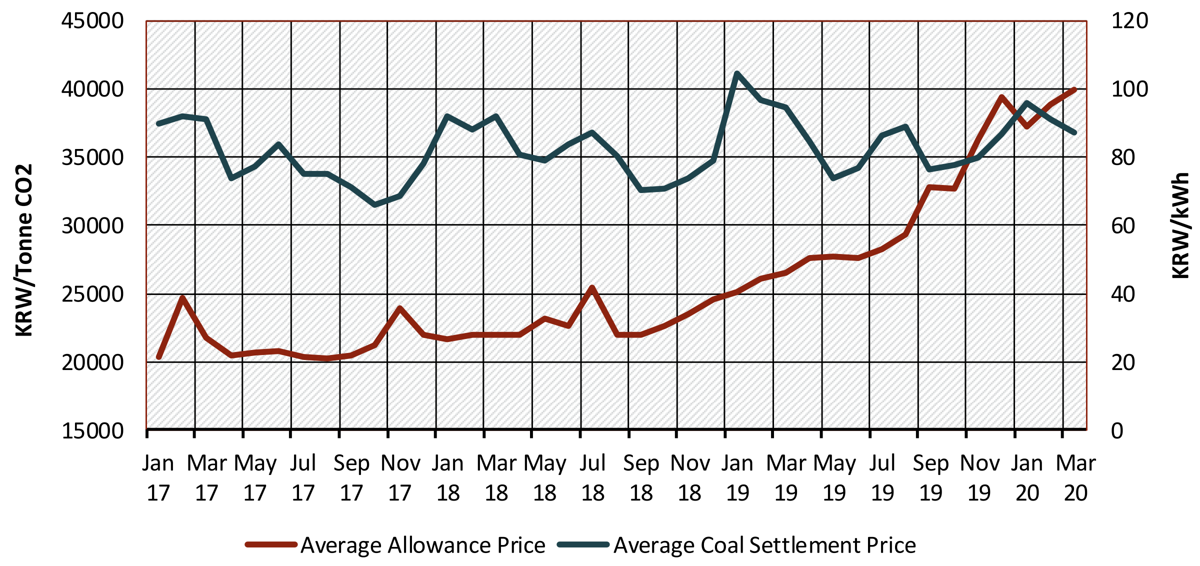
5 Impact of the K-ETS and the electricity sector on opportunities for abatement

The ETS has delivered a price signal that, if fully reflected in operational cost structures, can help incentivise a shift to cleaner production profiles and support policies promoting LNG-to-power and increased RE deployment. However, to do so, the allowance price signal must be transmitted to both producers and consumers of electricity and reflected in operation and investment decisions. For that to happen, K-ETS and electricity sector regulations must align.

5.1 Carbon cost pass through in wholesale electricity

In its current design, K-ETS allowance costs are not reflected in the SMP calculation that sets marginal wholesale electricity prices. This means that the K-ETS will not encourage a low carbon dispatch of generation sources. This is relevant for gas-fired power plants which cannot capitalise on their lower carbon-intensity vis-à-vis coal units. With wholesale prices not reflecting the cost of allowances, fuel costs largely determine OPEX profiles reflected in the SMP where gas units are likely to remain at the margin of the merit order. Lack of pass-through further affects VREs, such as wind power and solar PV units, through foregone electricity price and revenue increases affecting their net present value (NPV). This is set to change with the introduction of environmental dispatch possibly by 2022-2024 or through the gradual introduction of a PBP from 2023 onwards, both reforms that could in principal reflect net allowance costs in the SMP (MoE 2020g). These options are currently under discussion with a timeline for policy decision and implementation not yet clear.

Figure 12: Monthly average settlement prices for bituminous coal-fired power generation and KAUs in the respective vintage years



Source: Authors' elaboration based on data from the KRX and EPSIS

5.2 Fuel switch: Impact of carbon price on dispatch decisions

5.2.1 The Compensation Mechanism

Under current market regulations, generators with compliance obligations receive additional compensation alongside wholesale electricity prices to cover the cost difference between the actual emissions of a power plant and the amount of allowances that were freely allocated to it. The compensation mechanism was introduced to avoid exposing power producers to financial losses and prevent price increases reflected through the SMP.

According to the experts interviewed for this case study, this compensation mechanism can be seen as a government subsidy implemented by the KPX. The fact that power plants are compensated for their carbon cost by a subsidy mechanism that is external to the electricity market (SMP and CP) indicates the government's priority to protect consumers and industry from price increases, *in casu* price increases caused by the ETS. However, this arrangement distorts the impact that the ETS is supposed to have on the electricity sector.[36] By decreasing the cost efficiency of abatement under the K-ETS it has likely resulted in welfare loss (Kim & Lim 2020).

Allowing producers to fully recover the costs of buying allowances neutralises the intended effect of the ETS as emission reduction/control mechanism and may creating perverse incentives for abusing market power. To this end, the regulator has introduced volume and price limits as to discipline power producers' buying of allowances on the market. First, the actual level of compensation paid is linked to "benchmark emissions", which are determined for each power station based on the standard carbon intensity of the corresponding generation technology (tCO2eq/MWh), and the amount of electricity produced during the year. Compensation cannot exceed the actual purchase costs of allowances by power producers and is based on the net average cost of allowances purchased.

In this context, the introduction of benchmark emissions aims to control the emissions of power plants under the ETS by avoiding excessive compensation of their allowance transactions. By setting a limit to the financial compensation of allowances, the regulator can incentivise power stations to keep their emissions within certain limits. According to one interviewee, the compensation formula was designed to provide a slight incentive for efficiency within fuel types (coal, gas). However, it is not considered as an effective measure to incentivise GHG emission reductions, since the net cost incentive is small and there is a large time lap between the compliance year and receiving any compensation.

Were power stations compensated without limit for the purchase of allowances on the market, they may have faced an incentive to purchase more allowances than what was required for compliance to bank for future periods. However, such a strategy would have also been constrained to some extent by rules surrounding banking (Chapter 2.2.3). The proper functioning of the volume and price constraints depends on the adequate calculation of the benchmark emissions, the volume of electricity transactions, and the reference price of carbon transactions. One expert interviewed for this case study believes that the compensation mechanism did incentivise producers to buy more allowances than what they needed and blames the compensation mechanism for having contributed to the strong increase of the carbon price over the years. This criticism finds support in the fact that power producers were the most active buyers of allowances on the ETS (Chapter 3.2.2).

With the SMP not reflecting allowance costs and conventional generators being compensated for net purchasing costs, the K-ETS has had a negligible impact on the electricity sector. This may change with newly proposed electricity market reforms as discussed in the sections that follow.

[36] On these distortions, see e.g., Kim (2015).

5.2.2 Environmental dispatch

Currently, Korean power plants are dispatched based on technology benchmarks and corresponding OPEX profiles set by the regulator, which as described above do not factor in allowances costs. In the 8th BPLE, the government states its objective to internalise carbon costs in the electricity market by "harmonising economic load and environmental dispatch considerations" (MOTIE, 2017, p. 15). Referred to as environmental dispatch, this is intended to support the competitiveness of LNG plants vis-à-vis coal plants, and facilitate a fuel switch towards less polluting sources of electricity (MOTIE, 2019, p. 57; MOTIE, 2017).[37] Environmental dispatch may be introduced by 2022 and become fully operational by 2024 (MoE 2020g).

The dispatch mechanism would ensure that generators' net allowance costs are reflected in day-ahead bids. Under the draft proposal[38] submitted by KRX in December 2019, the cost of purchasing allowances are to be included in the SMP by the Cost Evaluation Committee next to fuel costs and operational expenditures. Power plant operators would have to submit emissions and market data to the Cost Evaluation Committee required for calculating the cost of allowances for each generator ("Electric power exchange decides", 2019). As power generators would be remunerated from net allowance costs through the SMP, the compensation scheme for carbon allowances would then be abolished.

Allocation rules become critical in determining the net allowance costs and therefore the proportion of carbon price pass-through that is reflected in the SMP.[39] Given low shares of auctioning and reasonably generous benchmarks–particularly for gas units[40] that often set the SMP, the impact of the reform on the electricity market is initially expected to be low. Some experts even pointed to the possibility that net costs could initially be negative where gas generators receive more allowances than they require for their own compliance and profit from selling surplus allowances. However, as the share of auctioning increases and benchmarks tighten over time, conventional generators will be required to purchase an increasing share of allowances and hence a greater proportion of allowance costs will be reflected in the SMP.

Environmental dispatch would help streamline existing market-based environmental regulations. In contrast to K-ETS compliance costs, fossil fuel taxes (i.e., the "Individual Consumption Tax") are already included in the SMP. However, current tax levels are not sufficient to reflect environmental externalities into the price of electricity (Cho & Park, 2019). Until recently, coal taxes were lower relative to LNG (ibid). This changed with a tax reform in April 2019 that increased levies on coal for electricity generation from 36 KRW/kg in 2018 to 46 KRW/kg, and decreased levies on LNG from 91.4 to 23 KRW/kg (MOE, 2020b). LNG was also subject to import duties of 24.2 KRW/kg as of 2019 (Lee, Park and Kim 2019). In addition to fuel taxes, the Clean Air Conservation Act imposes air pollutant emission charges for particulate matter (770KRW/kg (EUR 0.59/KG)) and for SOx (500KRW/kg (EUR 0.42/KG)) (Cho & Park, 2019).

The Korean government uses multiple instruments alongside the ETS and environmental dispatch to achieve its decarbonisation objectives. Higher taxes on coal are a key part of the

[37] With environmental dispatch, it is expected that the production cost of coal-fired power plants will be increased by 19.2 won/kWh and 8.2 won/kWh for LNG (MOTIE, 2017, p.42).

[38] Amendment to the Rules on Operation of the Electricity Market

[39] Under 100% free allocation, changes in the SMP would be zero, while under 100% auctioning changes in the SMP would reflect the market price for allowances on a tCO_2/MWh basis (full cost reflection).

[40] As summarised in Table 3 (Chapter 2.2.3), a uniform benchmark for coal and gas units is scheduled to be introduced in 2024 contingent on the introduction of environmental dispatch. This benchmark is based on the average carbon intensity of both generation technologies and would entail a near doubling of free allocation to gas-fired CHP plants, which often are price setters (i.e., the marginal unit) in the electricity market.

ROK's strategy to promote a shift to LNG. As LNG is a less carbon intensive source, this policy will inevitably have an impact on the ETS. Surprisingly, few analyses examine the combined impact of ETS and taxes on the merit order. For instance, Cho and Park do not mention carbon prices and the ETS in their 2019 study, although their analysis covers the reduction of GHG emissions that can result from tax changes. Similarly, Chang and Rho (2019) argue that "it is imperative that institutional improvements be made to strengthen the profitability of LNG generation, which is sensitive to changes in market conditions", without mentioning the role of the ETS in levelling the playing field between coal and LNG . The French Institute of International Relations states in general terms that the "coal-gas competition will be altered significantly by the adjustments made to fuel consumption taxes, the adoption of an environmental tax and the rising price of CO_2 in the K-ETS. This will gradually erode the competitiveness of coal against gas and reinforce the role of gas in the future" (Cornot-Gandolphe, 2018).

Although the debate surrounding environmental dispatch is focussed on ensuring carbon costs are passed through, our interviews indicate that the government plans to use this mechanism to achieve its local air protection objectives (i.e., the reduction of fine dust) next to reducing emissions. This interpretation is supported by the official objectives articulated in the 8th and 9th BPLE and 3rd Energy Basic Plan (section 4.4.3.3).

5.2.2.1 Price-based pool market – competitive bidding

There has been ongoing discussion in Korean policy circles about introducing a PBP to replace the CBP market (Jeong 2020; Park 2019). A PBP market decentralises price discovery by allowing producers to submit bids according to their individual cost profiles on the day-ahead market and broadens the role of market mechanisms in balancing supply and demand closer to real time. Government officials have announced that the PBP will be introduced in several stages recently confirmed in the 9th BPLE (Lee 2020; MOTIE, 2020b).

These steps will likely entail the introduction of limited price bidding in 2023, and a full transition from 2025 including the creation of a real-time market, capacity market, the introduction of market procurement for ancillary services and the abolishment of settlement adjustment factors (Jeong 2020). This would be a major step in Korea's electricity sector reform process and would help facilitate the integration of larger shares of variable renewable energy sources (IEA 2016; IRENA 2017).

It will also be a crucial step for alignment with the ETS. In principle, PBP systems enable carbon costs to be passed onto wholesale consumers (Wild, Bell & Foster 2015), including the opportunity costs of allowances received for free. A PBP market would as such negate the need for an additional allowance cost reflection mechanism, such as environmental dispatch. In practice, the two will go together with environmental costs being introduced in dispatch decisions as part of broader market reforms in the transition towards competitive bidding (MOTIE, 2020b). Detailed regulations on the scope of carbon costs to be reflected in generators' supply bids have yet to be released. Initially, price liberalisation could be limited such that only net allowance costs can be included in generators' bids, thereby aligning pool market reforms with the environmental dispatch mechanism outlined above.

The MoE (2020g) refers to the PBP market in the Phase 3 Allocation Plan of the K-ETS and plans to maintain fuel-specific benchmarks should the first steps of competitive bidding be introduced in 2023 (Table 3). In this scenario, allocation benchmarks for coal and gas gradually converge, thereby decreasing costs for gas and increasing costs for coal under the ETS, though to lesser extent than the uniform benchmark under environmental dispatch.

Although the exact details and timeline of implementation are subject to change, a PBP market will most likely be the long-term policy option for Korea's electricity sector design.

5.2.3 Impact of market structure and design

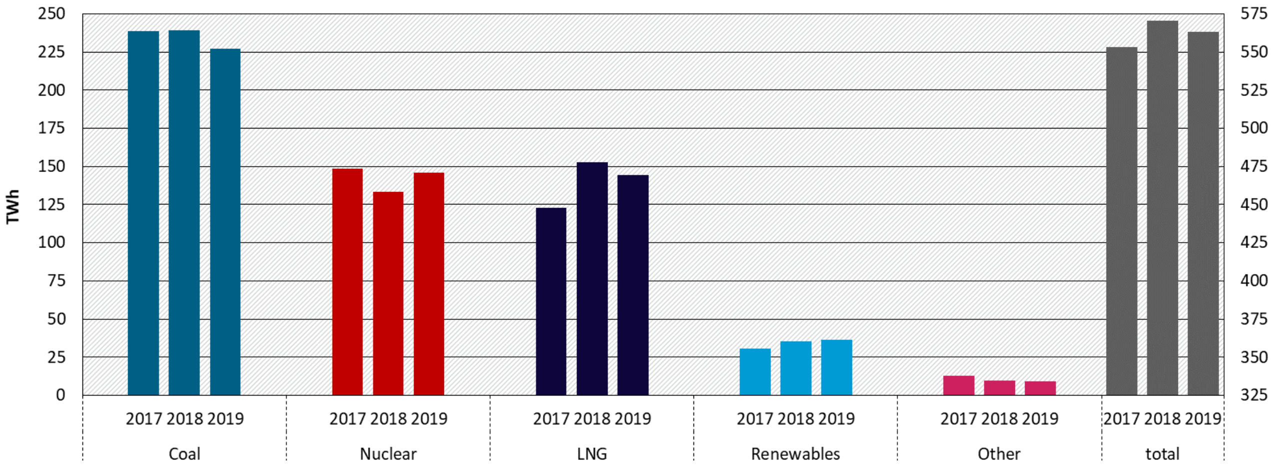
The structure of the Korean electricity sector indicates high potential for fuel switching. This is supported by a recent modelling analysis by the Korean Environment Institute. Kim (2019) finds that were carbon prices to be passed on to electricity prices, a moderate carbon price between KRW 30,000–40,000 (EUR 23 – 30) would trigger coal-to-gas switching, where a price of KRW 60,000 (EUR 46) could reduce sectoral emissions by around 40%. Price levels already observed in Phase 2 of the K-ETS can therefore trigger substantial sectoral abatement given alignment of the K-ETS with electricity sector regulation.

The high clean dispatch potential in Korea's electricity sector can be attributed to years of energy policy aimed at diversifying the capacity mix. Korea's gas-fired capacity stood at 40.7 GW in 2019, or 33.1% of total installed capacity consisting mostly of mid-load plants (combined cycle or CHP). In the same year, gas units accounted for 26% of total electricity generation (EPSIS 2020). Market settlement rules (such as adjustment factors) and capacity payments have been important revenue streams for Korea's growing gas fleet. Explained in detail in Chapter 4.2, the ROK is planning on increasing investment in gas-fired generation accompanying a mix of policies that support further market uptake.

Due to a relatively young coal feet (averaging 16 years), Korea's electricity system runs on relatively efficient coal power (ranging around 39% average efficiency for coal plants in 2019) (EPSIS, n.d.).[41] Coal-fired power generation in Korea will remain relatively efficient through the ROK's phase-down plan that limits plant lifecycles to 30 years ensuring only the newest technologies are used. With lower overall fuel costs per MWh of coal-fired power generation a stronger carbon price is needed to ensure the competitiveness of gas-fired plants. Changes to the consumption tax on fossil fuels described above will complement environmental or competitive bidding dispatch and effectively strengthen the price signal passed through from the K-ETS. The effect of the K-ETS on dispatching decisions will further hinge on dynamics in regional energy markets. The oil price crisis of 2020 created more favourable economics for coal-to-gas switching in Asia due to its impact on oil-index LNG (Wood Mackenzie 2020). However, oil prices have since risen again confirming that such dynamics should not be relied upon to drive fuel switching over the medium to long term.

[41] In 2015 Korea was level with China and just behind Germany on coal power plant efficiency and slightly more efficient than the world average (GE, 2015).

Figure 13: Electricity generation by fuel source (left axis) and total (right axis) for 2017 – 2019



Source: Authors' elaboration based on data from EPSIS (2020).

Once allowances costs are reflected in wholesale energy trading, the K-ETS will facilitate a more efficient use of low-carbon sources (nuclear, LNG and renewables) pushing coal towards the margin. However, the carbon price will then also interact with a range of existing energy policy instruments. Two of these, the RPS and fine dust regulations, have had a substantial impact on electricity generation, in Figure 13 reflected by gradually rising RE generation and stalling or decreasing coal output despite overall demand growth. Command and control regulations, such as Korea's air quality and fine dust measures, can limit the carbon price in driving fuel switching effects by dictating coal plants' utilization rates. These regulations play an important role in achieving the target scenario of a 29.9% coal generation share by 2030 as laid out in the 9th BPLE. Yet, given a credible price signal the ETS may also reduce the additionality of fine dust regulations over time as coal units are pushed out of baseload generation. Aligning these instruments as carbon costs are passed on will be important to ensure efficient abatement outcomes.

5.3 Impact of the carbon price on investment

The K-ETS works alongside a range of policy instruments that steer the electricity sector on a low-carbon trajectory. Decisions on energy investments, mothballing and decommissioning are primarily MOTIE's responsibility, which through energy supply plans sets a long-term framework for technology-specific capacity additions and efficiency standards. These are accompanied by a range of instruments analysed in the previous chapter, such as the RPS scheme, coal and nuclear phase-out policies, air quality measures, the consumption tax for conventional generators, and wholesale price design reflected in the SMP and CP.

The carbon price under the ETS has not yet played a determining role in guiding investments towards cleaner alternatives in the electricity sector.[42] Furthermore, the predictability of investment conditions suffers from the multiple policy roadmaps that investors have to take into account when proposing their investments, including the Energy Plan (currently the Third Energy Plan), the Renewable Energy Plan (currently the 3020 Renewable Energy Plan), the BPLEs, the ETS allocation plan and the GHG roadmap.[43]

[42] Expert interviews.

[43] The Phase 3 Allocation Plan and 9th BPLE are to be released later in 2020.

Outside of the electricity sector, high price levels in the first years of Phase 2 of the K-ETS were seen to have encouraged participants to focus on meeting benchmark levels for free allocation. For power generators, this incentive has been blocked by the special compensation mechanism. The current pricing structure, featuring no pass through and net cost compensation, negates the effect of the K-ETS on low-carbon investment in the electricity sector and maintains the internal rate of return on carbon-intensive assets. Since the compensation mechanism applies a fuel-based benchmark, where compensation for net allowance costs is only received if emissions are at or below the carbon intensity of the benchmark-standard unit, the least efficient technologies would face an incentive to converge towards that emissions level. However, given the marginal share of total allowance costs, this effect has been negligible (MoEF, MoE 2019).

Experience with existing ETSs has demonstrated that uniform benchmarks can encourage technology switching. The (net cost) environmental dispatch mechanism is unlikely to yield such results with the proposed benchmark for coal and gas (Table 3) and a lower price environment (Figure 3), but offers the opportunity to ratchet up ambition by increasing auctioning shares. This in turn will increase revenues for low carbon generators and encourage their investments.

Competitive bidding in a PBP market will offer greater opportunities for the carbon price to drive investments. If opportunity costs of allowances are reflected in dispatch decisions, clean dispatch effects can occur while low-carbon sources benefit from increased returns on the energy market. In this scenario, the ETS would support the internal rate of return of both gas and low-carbon sources at the expense of coal. While full auctioning would prevent windfall profits for carbon-intensive assets, targeted benchmarked allocation for coal units can serve to offset diminishing returns and smoothen the transition towards LNG and low-carbon sources. In this scenario, a balance will need to be struck between effective electricity sector abatement and the objective to minimise electricity price increases, an issue which we will return to in Chapter 5.4.

In conclusion, given the current interaction of the K-ETS and electricity sector, it is difficult to see the ETS playing a large role in driving low-cost investments. This will change with proposed market reforms for environmental dispatch and competitive bidding. In addition, the "information signal" that the cap trajectory sets should not be taken for granted in terms of precluding new high carbon investments.

5.3.1 Impact of market structure and design

Korea's moderately growing electricity demand, the phase down of coal and nuclear power, and the objective to rapidly increase the share of renewables and gas-fired power will require vast investments to meet both energy security and decarbonisation objectives. A predictable, rising allowance price that is internalised in generators' operational costs can help facilitate the shift towards low-carbon technologies. The impact of the carbon price will hinge on the market structures, regulations, and companion policies that shape the electricity system and its potential to accommodate a transforming power mix.

First, capacity payments will positively interact with the allowance price to encourage investment in gas-fired power as both reward a cleaner production profile. The proposed environmental dispatch mechanism can also support RE through a higher SMP, so long as generators at the margin face positive allowance costs. While this might not be the case in the coming years, as allocation becomes more stringent, the role of environmental dispatch in supporting RE deployment will increase. Similarly, a PBP can support RE deployment assuming allowance costs can be reflected in generators' bids. An ETS is only so effective in promoting renewable uptake as market regulations exist to facilitate their integration in the power mix. In Korea, priority dispatch for renewables ensures their utilization rates. This policy will remain an important condition for renewable capacity growth until intraday trading and further market integration can accommodate increasing variable supply.

The RPS has been an important policy for driving RE investment. Assuming cost pass through, it will likely lower the impact of the carbon price by directly incentivising abatement (i.e., it rewards each MWh of renewable electricity generated) that could have been attained under the K-ETS. It may also limit investments beyond what is required to meet RPS obligations. Abatement driven by the RPS exerts downward pressure on the allowance price and may impede the strength of the price signal when renewable generation shares accelerate towards 2030 and beyond. Whether the K-ETS or technology mandates drive RE investment going forward will depend on the level of ambition reflected in complementary policies versus the ETS cap, market stability measures, and the success of reform efforts that would ensure allowances costs are reflected in wholesale electricity prices.

With respect to conventional generation, the age of the coal fleet is important. Due to Korea's relatively young coal fleet, the cost of stranded assets will be larger in an early phase out scenario driven by high carbon prices. Even then, capacity payments to coal generators will work against the K-ETS while the closure of older units is mandated by the lifecycle cap. In this environment, retrofit investments become the next abatement option the K-ETS can support—once carbon costs are passed on to producers.

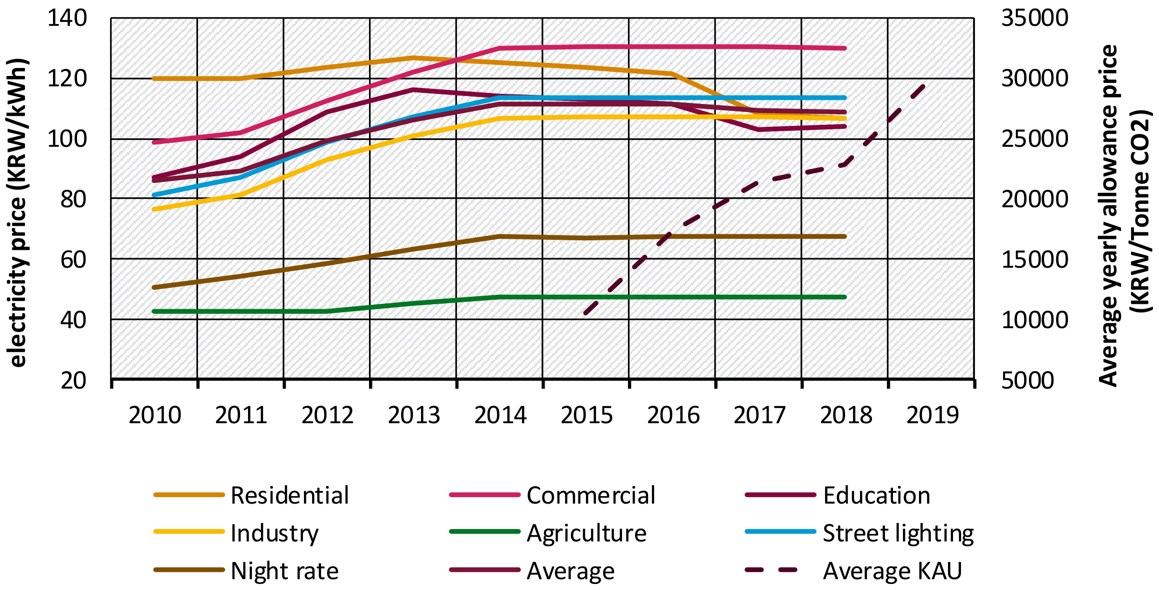
Retrofitting features prominently in the government's coal phase out strategy, which reflects the young age of the fleet, its sheer size and the crucial role for electricity supply and has therefore centred on how existing capacity can be best utilised in the country's decarbonisation pathway. The 9th BPLE earmarks 24 coal plants for coal-to-gas retrofit and six for early closure by 2034, in line with the 30-year lifecycle cap (MOTIE, 2020b). This will limit the effect of the carbon price in driving (dis)investment but can leave a role for the K-ETS in providing additional economic rationale guiding the "selection" process. Given large water entitlements and available grid infrastructure, opportunities also arise to convert coal plant sites to support a decarbonised power system through renewable hydrogen production as has recently been initiated by a consortium in Germany (see Vattenfall, 2021). Such innovative solutions can bolster Korea's Hydrogen Economy Roadmap which targets 15 GW of fuel cell power plant capacity by 2040 (Stangarone, 2020).

Other retrofits provide opportunities for the existing coal fleet to support the transition going forward. For (young) coal plants, carbon capture and storage (CCS) could become an important abatement technology but would require high carbon prices. In parallel, the introduction of short-term wholesale and balancing markets can offer a role for coal plants to accommodate increasing system flexibility needs (Agora Energiewende, 2017). By pricing short-term scarcity and flexibility, these markets can broaden the impact of the carbon price to incentivising corresponding retrofit investments (e.g., improving start-up times and ramp rates). Electricity market reforms envisaged beyond 2024 could have significant potential to align conventional generation with decarbonisation objectives by ensuring the most polluting technologies produce less, and when it matters most.

5.4 Demand-side response and carbon cost pass through in retail electricity

Owing to the K-ETS' coverage of indirect emissions from power generation, pass-through effects are mirrored for large electricity consumers (Coverage 2.2.6). Interviews conducted for this study indicate that demand-side responses have so far been limited. However, this may change when free allocation shares decline and large consumers face a net cost incentive that rises over time.

Figure 14: Retail Electricity Prices Korea and K-ETS allowance price



Source: Authors' elaboration based on data from EPSIS and the ICAP Allowance Price Explorer.

Smaller end-use consumers were not charged for allowance costs imposed by the K-ETS in Phase 1 and 2. As explained in Chapter 4.4.2.5, subsidised retail electricity tariffs have applied based on political and socio-economic considerations. This negates the downstream impact of the K-ETS (i.e. demand-side responses such as investments in energy efficiency and low-carbon distributed energy sources) and may prompt inefficient energy use, higher emissions and grid congestion.[44] Moreover, subsidised tariffs can impose financial losses on the part of electricity utilities and suppliers. This has been an issue of growing concern to KEPCO, which despite partial compensation by the government and burden sharing by its subsidiaries has incurred growing losses due to unrecoverable costs.

Net allowance costs for the power sector have up to Phase 2 of the K-ETS been incurred by the KPX through its compensation scheme to power generators. With the introduction of environmental dispatch or competitive bidding this cost factor would shift to KEPCO, which as the single buyer would have to pay higher wholesale prices. Pass-through of carbon costs to wholesale electricity prices may hence widen the gap between recoverable rates and the SMP if not accompanied with retail tariff reforms—as well as a gradual phase out of indirect emissions coverage—that would bring electricity rates more in line with overall production costs. Such a situation would become untenable for KEPCO unless it receives further government support. The introduction of a separate climate rate to the retail tariff scheme in January 2021 is promising as it sets a mechanism for cost recovery that will become increasingly relevant as higher shares of allowance costs are reflected in wholesale electricity prices over the coming years. To be successful, the climate rate, or retail tariffs more broadly, will need to be kept at pace with rising costs under the ETS. This will require continued commitment to curb tariff subsidies to support the financial sustainability of Korea's power sector in transition.

[44] More generally, on the implications of artificially low electricity prices for industrial consumers in Korea for the functioning of the Korean electricity sector, see Pittman (2014).

5.4.1 Impact of market structure and design

Retail tariffs are a crucial element in the discussion surrounding carbon cost pass through. Without cost-reflective rates, additional financial support will be necessary to avoid debt accumulation on the part of retail companies as environmental costs increase. This trade off with highly affordable but subsidised retail prices must be navigated as the government continues to assess tariff structures and broader climate policy objectives.

The pass-through of carbon costs to end-user prices may also impact interactions in the heating sector through competition between CHP/district heating and gas supply, in particular the threat of "boilerisation", i.e. consumers shifting from district heating to individual gas boilers.[45] Reduced demand for district heating due to the increased use of individual boilers may pose a risk of carbon leakage. Contrary to CHP plants, smaller individual boilers are not covered by the ETS. Reduced ETS emissions from CHP/district heating would as such be offset by increased emissions from individual boilers that remain outside of the ETS. As more than 16% of the Korean population is connected to and supplied with district heating (Kim, Kim, and Yoo, 2020) and CHP and heat plants are important consumers of natural gas,[46] the size effect could potentially be significant. However, significant differences in the consumer basis and cost profile of district heating and urban gas companies (Oh, 2019), as well as specific consumer habits in Korea, make it difficult to determine exactly what level of heat price increases, following pass-through, would influence a shift to individual gas boilers.[47]

[45] See e.g., (Boute, 2012).

[46] With CHP and heat plants amounting to respectively 442464 and 3414 TJ, compared to 762 021 TJ for electricity plants in 2018, according to the IEA statistics, https://www.iea.org/data-and-statistics/data-tables?country=KOREA&energy=Natural%20gas&year=2018 (note however the broad definition of CHP installations by the IEA). See Min, Lim, Yoo (2019), referring to an "actual share" of 8.6% CHP in 2017 and an "optimal share" of 13.8%.

47 On the absence of comparative data on individual heating and district heating systems, see also Kim, Kim, and Yoo (2020).

References

Acworth, W., Kardish, C., and Kellner, K. (2020): Carbon Leakage and Deep Decarbonization: Future-proofing Carbon Leakage Protection. Berlin: ICAP.

Acworth, W.; Kuneman, E.; La Hoz Theuer, S.; et al. (2019): Influence of market structures and market regulation on the carbon market. DEHST, Berlin. Available: https://www.dehst.de/SharedDocs/downloads/EN/publications/report_influence-of-market-structures-and-market-regulation.pdf?__blob=publicationFile&v=3.

Agora Energiewende (2017): Flexibility in thermal power plants – With a focus on existing coal-fired power plants.

Ahn, Y. (2019): Study on the use of consignment auction to foster the emissions allowances market. Policy Issue paper 19-07, Korea Energy Economics Institute, Ulsan.

Asian Development Bank (ADB) (2014): Power Sector in Developing Asia – Current Status and Policy Issues. In: ADB Economics Working Paper Series, 2014, 405, ADB, Manila. Available: https://www.adb.org/sites/default/files/publication/42879/ewp-405.pdf

Asian Development Bank (ADB) (2018): The Korea Emissions Trading Scheme – Challenges and Emerging Opportunities. ADB, Manila.

Bae, Kim & Lee LLC (2018): Power Generation in South Korea. Lexicology. Available: https://www.lexology.com/library/detail.aspx?g=9b23a9d5-08f7-49ef-a453-481a5fe0deb7

Barroso, L. A.; Cavalcanti, T. H.; Giesbertz, P.; Purchala, K. (2005): Classification of electricity market models worldwide. In International Symposium CIGRE/IEEE PES, 2005. (pp. 9-16). IEEE.

Brunner, S.; Flachsland, C.; Luderer, G.; Edenhofer O. (2009): Emissions Trading Systems – An overview. Potsdam Institute for Climate Impact Research (PIK), Potsdam. Available: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.535.2125&rep=rep1&type=pdf

Chang, H.; Rho, D. (2019): Improvement of Power Industry Regulations and Competition Policy in an Energy Transition Era. Policy Issue Paper 19-04, Korea Energy Economics Institute, Ulsan. Available: http://www.keei.re.kr/web_keei/en_publish.nsf/by_report_types/5D485DF0BBED3278492584E70018051D/$file/PIP1904e.pdf

Cho, S. and Park, G. (2019): A Study on Tax Revisions to Achieve Energy Transition in the Power Sector. Policy Paper 19-05, Korea Energy Economics Institute. Available: http://www.keei.re.kr/web_keei/en_publish.nsf/by_report_types/40180ECD6ED3D81D492584E7001FB365/$file/PIP1905e.pdf

Chung, J. (2019): S. Korea Plans Closure of Up to 15 Coal Power Plants for Winter. https://www.reuters.com/article/us-southkorea-power-coal/south-korea-plans-to-shut-down-up-to-15-coal-fired-power-plants-this-winter-idUSKBN1Y205J (30.07.2020)

Chung, J.; Kim, E. (2018): Public Perception of the Energy Transition in Korea – Nuclear Power, Climate Change, and Party Preference. Energy Policy, 116, p. 137-144

Chung, W.S.; Kim, S.S.; Moon, K.H.; Lim, C.Y.; Yun, S.W. (2017): A conceptual framework for energy security evaluation of power sources in South Korea. Energy, 2017, 137(1), p. 1066–1074.

Civil Act (1958): Act No. 11728. Available: https://elaw.klri.re.kr/eng_service/lawView.do?hseq=29453&lang=ENG

Climate Analytics (2020): Transitioning toward a coal-free society – science-based coal-phase out pathway for South Korea under the Paris Agreement. Available:

https://climateanalytics.org/publications/2020/transitioning-toward-a-coal-free-society-science-based-coal-phase-out-pathway-for-south-korea-under-the-paris-agreement/

CNews Korea (2019): Electric power exchange decides to revise market operation rules. http://cnews.co.kr/m_home/view.jsp?idxno=201912161335007360672 (30.07.2020)

Cornot-Gandolphe, S. (2018): South Korea's New Electricity Plan: Cosmetic Changes or a Breakthrough for the Climate? French Institute of International Relations, Paris. Available: https://www.ifri.org/en/publications/editoriaux-de-lifri/edito-energie/south-koreas-new-electricity-plan-cosmetic-changes-or

ECOEYE International (2018a): January 2018: Korea ETS Phase 1 Review. http://ecoeye-int.com/board/board.php?bo_table=news&idx=36 (30.07.2020)

ECOEYE International (2018b): August 2018: Korean Market Update. http://ecoeye-int.com/board/board.php?bo_table=news&idx=43 (30.07.2020)

ECOEYE International (2018c): December 2018: Korean Market Update. http://ecoeye-int.com/board/board.php?bo_table=news&idx=47 (30.07.2020)

ECOEYE International (2019a): May 2019: Korean Market Update. http://ecoeye-int.com/board/board.php?bo_table=news&idx=56 (30.07.2020)

ECOEYE International (2019b): November 2019: Korean Market Update. http://ecoeye-int.com/board/board.php?bo_table=news&idx=62 (30.07.2020)

ECOEYE International (2020): April 2020: Korean Market Update. http://ecoeye-int.com/board/board.php?bo_table=news&idx=69 (30.07.2020)

Eco & Partners Co., Ltd. (2018): Final Report on BM Allocation Scheme for the 2nd Emission Trading Scheme. Available: http://www.prism.go.kr/homepage/researchCommon/downloadResearchAttachFile.do;jsessionid=FD3BED0BA116B393D6B514E67E750545.node02?work_key=001&file_type=CPR&seq_no=001&pdf_conv_yn=Y&research_id=1480000-201800310

Electric Power Statistics Information System (EPSIS) (2019): Generation by Electric Power Source: Total. http://epsis.kpx.or.kr/epsisnew/selectEkgeGepTotChart.do?menuId=040201&locale=eng, (05.02.2020)

Electricity Market Surveillance Committee (EMSC) and Korea Power Exchange (KPX) (2019): Electricity Market Trends & Analysis – 2019 Annual Report.

EPSIS (2020): about EPSIS – Introduction. http://epsis.kpx.or.kr/epsisnew/selectEkccIntroEn.do?menuId=110100 (30.07.2020)

EPSIS 전력통계정보시스템 (n.d.): Thermal power plant thermal efficiency. https://epsis.kpx.or.kr/epsisnew/selectEkgeTepGrid.do?menuId=040400 (30.07.2020)

Farand, C. (2020): South Korea to implement Green New Deal after ruling party election win. https://www.climatechangenews.com/2020/04/16/south-korea-implement-green-new-deal-ruling-party-election-win/ (30.07.2020)

General Electrics (2015): GE Global Power Plant Efficiency Analysis. General Electrics, Boston, MA. Available: https://www.ge.com/reports/wp-content/themes/ge-reports/ge-power-plant/dist/pdf/GE%20Global%20Power%20Plant%20Efficiency%20Analysis.pdf

Greenhouse Gas Information Center (GGIC) (2020): National Greenhouse Gas Inventory Report of Korea 2019. GGIC, Seoul. Available: http://www.gir.go.kr/home/index.do?menuId=36

Greenhouse Gas Inventory and Research Center of Korea (GIR) (2019): K-ETS Summary Report – Phase I, 2015-2017. Ministry of Environment, Seoul.

GIR (2020a): 2018 K-ETS Summary Report. Ministry of Environment, Seoul.

GIR (2020b): Disclosure: Total quantity of allowances. https://etrs.gir.go.kr/home/index.do?menuId=12 (11.12.2020)

GIR (2021): 2019 Korean Emissions Trading System Report. Ministry of Environment, Seoul.

Hong, J. H. (2019): Long-term Energy Strategy Scenarios for South Korea – Transition to a Sustainable Energy System. Energy Policy, 2019, 127, p. 425.

Hong, S.; Brook, B. (2018): A Nuclear To Gas Transition in South Korea: Is It Environmentally Friendly or Economically Viable? Energy Policy, 2018, 112.

Huh, S.; Lee, J.; Shin, J. (2015): The Economic Value of South Korea's Renewable Energy Policies (RPS, RFS, And RHO): A Contingent Valuation Study. Renewable and Sustainable Energy Reviews, 2015, 50.

International Carbon Action Partnership (ICAP) (2020a): Emissions Trading Worldwide: Status Report 2020. Berlin: ICAP.

ICAP (2020b): Korea announces third-party participation and changes to allocation. https://icapcarbonaction.com/en/news-archive/704-korea-announces-third-party-participation-and-changes-to-allocation (30.07.2020)

ICAP (2020c). Allowance Price Explorer. https://icapcarbonaction.com/en/ets-prices (30.06.2020)

ICAP (2021): Emissions Trading Worldwide - Status Report 2021. Berlin: ICAP.

Institute for Energy Economics & Financial Analysis (2020): Government advisory group pushing quicker renewable transition for South Korea. https://ieefa.org/government-advisory-group-pushing-quicker-renewable-transition-for-south-korea/ (08.05.2020)

International Energy Agency (IEA) (2016): Re-Powering Markets. IEA, Paris.

IEA (2019a): Korea Renewable Energy 3020 Plan. IEA/IRENA Renewables Policies Database.

IEA (2019b): Korea Renewable Portfolio Standard (RPS). IEA/IRENA Renewables Policies Database.

IEA (2020): Key Energy Statistics, 2018: Germany. https://www.iea.org/countries/germany (30.07.2020)

IRENA (2017): Adapting market design to high shares of variable renewable energy. IRENA, Abu Dhabi.

Jeong, H. S. (2020): The coal and LNG generator markets are separated. https://www.electimes.com/article.php?aid=1591237021199658002 (04.06.2020)

Jeong, Y.; Park, G. (2019): Study on Ways of Improving the Time-of-Use Rate Plan. Policy Issue Paper 19-03, Korea Energy Economics Institute, Ulsan. Available: http://www.keei.re.kr/web_keei/en_publish.nsf/by_report_types/8FECFC9F172B2163492584E70016C8FB/$file/PIP1903e.pdf

Kahneman, D.; Knetsch, J. L.; Thaler, R. H. (1991): Anomalies: The endowment effect, loss aversion, and status quo bias. Journal of Economic perspectives, 1991, 5(1), p. 193-206

KEPCO (2013): About KEPCO: Overview. https://home.kepco.co.kr/kepco/EN/A/htmlView/ENAAHP001.do?menuCd=EN010101 (30.07.2020)

KEPCO (2016): Electricity Rates Table. https://home.kepco.co.kr/kepco/EN/F/htmlView/ENFBHP00101.do?menuCd=EN060201 (30.07.2020)

KEPCO (2017): KEPCO's Subsidiaries. Available: https://home.kepco.co.kr/kepco/EN/A/htmlView/ENACHP00301.do?menuCd=EN010403

KEPCO (2020): 2020 CEO Investor Day – IR Key Point. December 22.

KESIS (2020): Power generation by power source. http://www.kesis.net/sub/subChart.jsp?report_id=32150&reportType=0 (05.10.2020)

Kim, J. (2020): Uncertainty regarding REC Prices and Investments in Renewable Energy: Evidence from Korea. Available: https://dx.doi.org/10.2139/ssrn.3536788

Kim, J.C. (2020): Integration of coal and LNG emission factors. Energy Times, https://www.energytimes.kr/news/articleView.html?idxno=57618 (01.10.2020)

Kim, J. (2019): An Empirical Study on Efficiency in the Electric Power Industry - Focusing on Analysis of Cost Function. Policy Issue Paper 19-16, Korea Energy Economics Institute, Ulsan.

Kim, J. D.; Choi, E.; Lee, E. (2019): Social justice, fairness and exclusion in the South Korean electricity sector. Energy Research & Social Science, 2019, 51, p. 55-66

Kim, J. H. (2017): New and renewable electricity bidding market. Energy News, https://www.energy-news.co.kr/news/articleView.html?idxno=45510 (30.07.2020)

Kim, M. (2015): A study on the impact analysis of introducing emission trading system on CBP market and policy implications. The Transactions of The Korean Institute of Electrical Engineers, 2015, 64(5), p. 667-679

Kim, S., Kim, Y., and Shik Shin, J. (2013): The Korean electricity market: Stuck in Transition. Evolution of Global Electricity Markets, 2013, p. 679-713

Kim, Y. G.; Lim, J. S. (2020): Treatment of indirect emissions from the power sector in Korean emissions trading system. Environmental Economics and Policy Studies, 2020, p. 1-12.

Kim, Y.; Cho, C. H. (2020): Korea. In: Energy 2020. Global Legal Insights, London.

Kim, Y.; Hoon, T.; Lim, H. (2017): Research on System Improvement Plan for Activating the Carbon Emissions Market. Ministry of Strategy and Finance, Seoul. Available: http://www.prism.go.kr/homepage/researchCommon/downloadResearchAttachFile.do;jsessionid=400E8ED408AEB91A1A1423F5475B1326.node02?work_key=001&file_type=CPR&seq_no=002&pdf_conv_yn=Y&research_id=1051000-201800074

Kim, Yong-Gun (2019): Evaluation of Greenhouse Gas Reduction Potential in Power Sector – Mixed Integer Programming Approach. Korea Environment Institute, Sejong.

Kimura, S., and Ichimura S. (2019): Cost-profit analysis for Japan-Russia and Japan-South Korea interconnectors. Global Energy Interconnection, 2019, 2(2), p. 114-121

Ko, W.; Vettikalladi, H.; Song, S.H.; Choi, H.J. (2020): Implementation of a Demand-Side Management Solution for South Korea's Demand Response Program. Applied Sciences, 2020, 10, p. 1-14

Korean Electric Utility Act (2000). Available: http://extwprlegs1.fao.org/docs/pdf/kor169182.pdf

Korea Energy Agency (KEA) (2019): The Korea Energy Agency conducts competitive bidding for RPS fixed price contracts in the second half of the year. Available at : http://www.energy.or.kr/web/kem_home_new/energy_issue/mail_vol124/pdf/issue_227_03_01.pdf

Korea Legislative Research Institute (2017): Enforcement decree of the act on the allocation and trading of greenhouse gas emission permits. Available: https://elaw.klri.re.kr/eng_mobile/viewer.do?hseq=46598&type=sogan&key=60 (05.03.2020)

Korea Exchange (KRX) (2020). Market data: ETS Daily/Closing Price. http://global.krx.co.kr/contents/GLB/05/0506/0506030102/GLB0506030102.jsp (30.07.2020)

Korea Power Exchange (KPX) (2015). Electricity Market Operation Council. http://www.kpx.or.kr/eng/contents.do?key=304 (30.07.2020)

KPX (2019): Current Status of Members. https://www.kpx.or.kr/www/contents.do?key=55 (30.07.2020)

KPX (2020): Market Pricing. https://www.kpx.or.kr/www/contents.do?key=75 (30.07.2020)

Léautier, T.O. (2019): Imperfect Markets and Imperfect Regulation - An Introduction to the Microeconomics and Political Economy of Power Markets. MIT Press, Cambridge, MA

Lee, H. (2020): Power market reorganization essential for a sustainable green new deal. Monthly electric journal, http://www.keaj.kr/news/articleView.html?idxno=3662 (13.12.2020).

Lee, JH. (2019): KEPCO reports an operating loss, the first in six years. Korea JoongAng Daily. https://koreajoongangdaily.joins.com/news/article/article.aspx?aid=3059771 (30.07.2020)

Lee, JH. (2020): Understanding power system operation: the role of ancillary services. Monthly electrical journal, http://www.keaj.kr/news/articleView.html?idxno=3477 (05.10.2020).

Lee, SB. (2018): Maintenance and operation of the power system. Energy & Environment News, http://www.e2news.com/news/articleView.html?idxno=108187 (05.10.2020).

Lee, S. H. (2011): Electricity in Korea. In: APEC Secretariat: The Impacts and Benefits of Structural Reforms in Transport, Energy and Telecommunications Sectors, APEC, Singapore.

Lee, S.L.; Jeong, H.K.; Ma, Y.S.; Kim, Y. (2013): Study on the stabilization of the power market. In: Korea Energy Economics Institute, research report 13-07.

Lee, S. Y. (2017): Policy Directions for Activating Energy Prosumer. Presentation given at the 5th Northeast Asia Energy Security Forum, 12 December 2017, Seoul. Available: https://www.unescap.org/sites/default/files/Session%202-1.%20Yoo-Soo%20Lee_KEEI.pdf

Lee, Y-S.; Park, J-H.; Kim, J. (2019): Analysis of the current status of the energy tax system. Estimated Tax Analysis Office. Available in Korean here.

Lexology (2018): Electricity Regulation in South Korea. https://www.lexology.com/library/detail.aspx?g=4a7f6594-b6b4-4249-a928-a0e02ed683e5 (30.07.2020)

Lim, D. (2015): Experience with Emission Benchmarks: ETS Allocation in Korea. ECO&Partners, Seoul.

Ministry of Environment of Korea (MoE) (2017): 2nd Basic Emissions Trading Scheme Basic Plan. MoE, Seoul.

MoE (2019): Basic plan for the 3rd planning period of the emissions trading system. MoE, Seoul.

MoE (2015): Korean Credit Unit now tradable at Korea Exchange. http://eng.me.go.kr/eng/web/board/read.do?pagerOffset=220&maxPageItems=10&maxIndexPages=10&searchKey=&searchValue=&menuId=&orgCd=&boardId=501080&boardMasterId=522&boardCategoryId=&decorator= (26.03.2020)

MoE (2018): Phase 2 National Emissions Allocation Plan. MoE, Seoul.

MoE (2020a): Notice of amendment to the Enforcement Decree of the Emissions Trading Act. http://www.me.go.kr/home/web/board/read.do?menuId=286&boardMasterId=1&boardCategoryId=39&boardId=1366490 (24.04.2020).

MoE (2020b): Climate Economy Division, Press release – Companies subject to the emission trading system, the first reduction in greenhouse gas emissions. http://www.me.go.kr/home/web/board/read.do?pagerOffset=130&maxPageItems=10&maxIndexPages=10&s

earchKey=&searchValue=&menuId=286&orgCd=&boardId=1371090&boardMasterId=1&boardCategoryId=&decorator= (22.06.2020)

MoE (2020c): Green New Deal Promotion Task Force, Press release – Green New Deal towards carbon neutral society. http://www.me.go.kr/home/web/board/read.do?pagerOffset=30&maxPageItems=10&maxIndexPages=10&searchKey=&searchValue=&menuId=286&orgCd=&boardId=1385320&boardMasterId=1&boardCategoryId=&decorator= (30.07.2020)

MoE (2020d): Air Pollution. https://eng.me.go.kr/eng/web/index.do?menuId=464#:~:text=Responding%20to%20the%20need%20for,.%E2%80%9D%20Aiming%20to%20reduce%20PM2.&text=5%20concentration%20will%20decrease%20to,40%20for%20the%20same%20period. (05.08.2020)

MoE (2020e): Preparation of the national emission permit allocation plan for the 3rd planning period (2021–2025). MoE, Seoul

MoE (2020f): Information Management team, press release – Greenhouse gas emissions increased by 2.5% in 2018, decreased by 3.4% in 2019. http://www.me.go.kr/home/web/board/read.do?pagerOffset=10&maxPageItems=10&maxIndexPages=10&searchKey=&searchValue=&menuId=286&orgCd=&boardId=1400930&boardMasterId=1&boardCategoryId=&decorator= (06.10.2020).

MoE (2020g): Greenhouse Gas Emissions Trading System 3rd Plan Period (2021-2025) – National emission permit allocation plan, draft version. MoE, Seoul.

Ministry of Trade, Industry, and Energy, Korea (MOTIE) (2013): 6th Basic Plan for Long-term Electricity Supply and Demand. MOTIE, Seoul.

MOTIE (2017): 8th Basic Plan for Long-Term Electricity Supply and Demand. MOTIE, Seoul. Available in Korean: https://www.kpx.or.kr/www/downloadBbsFile.do?atchmnflNo=30051

MOTIE (2019): Third Energy Basic Plan. MOTIE, Seoul. Available in Korean: https://www.motie.go.kr/common/download.do?fid=bbs&bbs_cd_n=81&bbs_seq_n=161753&file_seq_n=1

MOTIE (2020): The ninth basic power supply plan – strategic environmental impact assessment. MOTIE, Seoul. Available in Korean: http://www.motie.go.kr/motie/ms/nt/announce3/bbs/bbsView.do?bbs_cd_n=6&bbs_seq_n=66035

MOTIE (2020b): The 9th Basic Plan for Electricity Supply and Demand. Ministry of Trade, Industry and Energy Announcement No. 2020-741

Oh, S. (2019): Policy Reform for District Heating in South Korea - Focusing on Increasing R&D Investment. Policy Issue Paper 19-02, Korea Energy Economics Institute, Ulsan. Available: http://www.keei.re.kr/web_keei/en_publish.nsf/by_report_types/9BFEDE54CAC20DF7492584E700166288/$file/PIP1902e.pdf.

Open Electricity Economics (2020): Chapter 5: Optimal capacity mix and scarcity pricing. Available: http://www.open-electricity-economics.org/book/text/05.html

Park, M.; Barrett, M.; Gallo Cassarino, T. (2019): Assessment of future renewable energy scenarios in South Korea based on costs, emissions and weather-driven hourly simulation. Renewable Energy, 2019, 143, p. 1388-1396

Park, J-B. (2019): Current status and direction to improve the variable cost market. Monthly Electric Journal, http://www.keaj.kr/news/articleView.html?idxno=2972 (05.10.2020)

Park, S.; Jung, W.; Kim, T.; Lee, S. T. (2016): Can renewable energy replace nuclear power in Korea? An economic valuation analysis. Nuclear Engineering and Technology, 2016, 48(2), p. 559-571

Pittman, R. (2014): Which Direction for South Korean Electricity Policy? Korean Energy Economic Review, 2014, 13

Reklev, S. (2015): KRX to list second carbon offset type from May. Carbon Pulse, https://carbon-pulse.com/13777/ (30.07.2020)

Reklev, S. (2020): South Korea approves first batch of overseas CDM projects. Carbon Pulse, https://carbon-pulse.com/93108/ (30.07.2020)

Renewable Energy Institute (2018): Asia International Grid Connection Study Group Second Report Summary. REI, Tokyo. Available: https://www.renewable-ei.org/en/activities/reports/img/pdf/20180614/REI_ASG_SecondReportSummary_EN.pdf

Republic of Korea (ROK) (2007): Special Consumption Tax Act. Act No. 8139. Available: https://ko.wikisource.org/wiki/%ED%8A%B9%EB%B3%84%EC%86%8C%EB%B9%84%EC%84%B8%EB%B2%95_(%EC%A0%9C8139%ED%98%B8)

ROK (2019): Special Act on Reduction and Management of Fine Dust. Act No. 16303. Available: https://elaw.klri.re.kr/eng_mobile/viewer.do?hseq=50524&type=sogan&key=16

ROK (2020): Submission under the Paris Agreement – The Republic of Korea's Update of its First Nationally Determined Contribution. December 30, 2020.

Seoul National University Nuclear Policy Center (SNEPC) (2018): Capacity price. Nuclear Knowledge Information Site, https://atomic.snu.ac.kr/index.php/%EC%9A%A9%EB%9F%89%EA%B0%80%EA%B2%A9 (31.07.2020)

Sioshansi, F. P. (2013): Evolution of global electricity markets – New paradigms, new challenges, new approaches. Academic Press, Cambridge, MA.

Son, D. et al. (2019): Optimal Operational Strategy for Power Producers in Korea Considering Renewable Portfolio Standards and Emissions Trading Schemes. Energies, 2019, 12, p. 1667

Stangarone, T. (2020): South Korean efforts to transition to a hydrogen economy. Clean Techn Environ Policy. https://doi.org/10.1007/s10098-020-01936-6

Suk, S.; Lee, S.; Jeong, Y. S. (2018): The Korean emissions trading scheme: Business perspectives on the early years of operations. Climate Policy, 2018, 18(6), p. 715-728

The Economist (2019): A muddy future: South Korea's government wants greener energy. Who will pay for it? The Economist, https://www.economist.com/asia/2019/06/15/south-koreas-government-wants-greener-energy-who-will-pay-for-it (30.07.2020)

Vattenfall. (2021): Vier Partner unterzeichnen Absichtserklärung über 100 MW Elektrolyse. https://group.vattenfall.com/de/newsroom/pressemitteilungen/2021/wasserstoffprojekt-am-standort-hamburg-moorburg (25.02.2021)

Vivid Economics (2011): Electricity Dispatch Regimes. Vivid Economics, London. Available: https://www.pc.gov.au/inquiries/completed/carbon-prices/report/carbon-prices-vivid-economics-dispatch.pdf

Wild, P.; Bell, W. P.; Foster, J. (2015): Impact of carbon prices on wholesale electricity prices and carbon pass-through rates in the Australian national electricity market. The Energy Journal, 2015, 36(3)

Wood Mackenzie (2020): Will coal-to-gas switching in Japan and South Korea finally become reality in a low oil price world? Wood Mackenzie, Edinburgh. Available: https://www.woodmac.com/reports/gas-markets-will-coal-to-gas-switching-in-japan-and-south-korea-finally-become-reality-in-a-low-oil-price-world-402425/