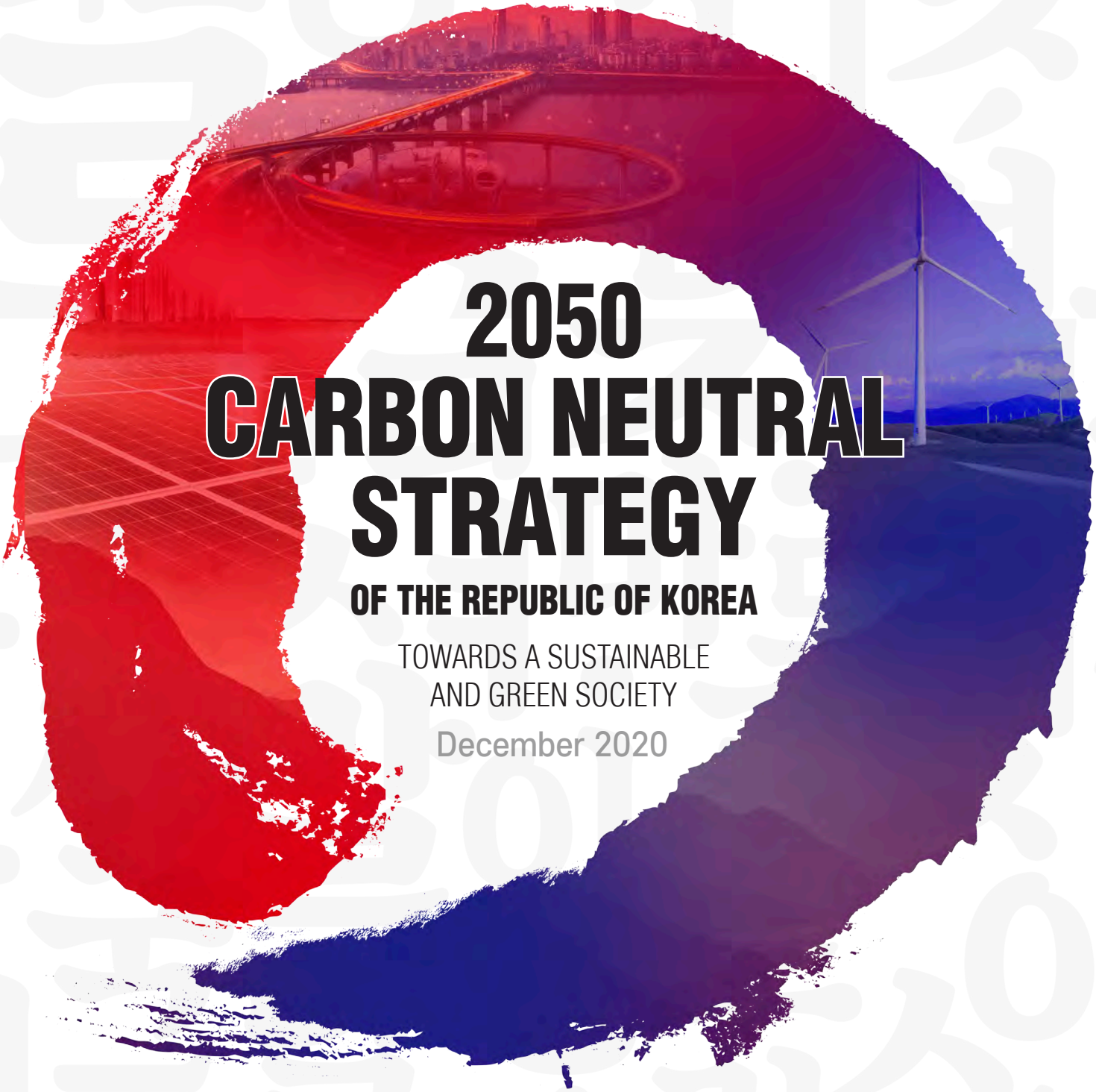

2050 CARBON NEUTRAL STRATEGY

OF THE REPUBLIC OF KOREA

TOWARDS A SUSTAINABLE
AND GREEN SOCIETY

December 2020

The Government of
the Republic of Korea

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This Strategy has been originally prepared in Korean language and this document is the English translation of the original Korean document.

CONTENTS

Executive Summary

1. Background

Why we should act now

Massive wildfires, typhoons, heatwaves, and snowstorms caused by global warming have become almost a part of daily life and can be seen easily around the globe. Korea is not immune to such effects of global warming. In Korea, the rate of warming accelerated in recent years, with the average temperature rise for the past 30 years reaching 1.4°C, and the warming is expected to pick up more speed in the coming years.

Recognizing the urgency of the climate change issue, the international community adopted the Kyoto Protocol in 1997 mandating developed countries to cut their greenhouse gas (GHG) emissions. The Paris Agreement joined by developing and developed countries was adopted in 2015 and entered into force on 4 November 2016 thanks to the active and coordinated efforts of the international community. Korea ratified the Agreement on 3 November 2016. The goal of the Paris Agreement is to hold the increase in the global average temperature to well below 2°C above pre-industrial levels and pursue efforts to limit the increase to 1.5°C above pre-industrial levels.

The Intergovernmental Panel on Climate Change (IPCC) adopted the Special Report on Global Warming of 1.5°C after intense discussions at its 48th session held in Incheon, Korea in October 2018. The Special Report provides solid scientific evidence for the 1.5°C target agreed by the international community when adopting the Paris Agreement.

The Special Report suggests pathways that global net anthropogenic CO_2 emissions decline by about 45% from 2010 levels by 2030, and reach net zero around 2050, for limiting global warming to 1.5°C by 2100.

How the long-term strategy was developed

The Paris Agreement recommends that all Parties strive to formulate and communicate Long-term low greenhouse gas Emission Development Strategies (LEDS) by 2020 as long-term vision for responding to climate change.

To participate in the efforts of the international community to address climate change, the Government of the Republic of Korea decided to develop its LEDS. The 2050 Low-carbon Vision Forum was established to listen to various opinions of experts from private sector in the preparatory stage of its LEDS. The Forum consisted of experts from academia,

industry, and civil society, who closely examined and reviewed a broad spectrum of options for Korea's vision and targets in reducing 2050 GHG emissions by 2050. The Forum drafted a proposal, which later was utilized for the Government's inter-ministerial discussions as well as for national consultations to collect opinions from diverse stakeholders in order to establish this Strategy.

Afterwards, a government-wide consultative body comprised of representatives from 15 ministries[1)] conducted online surveys, expert consultations, and public discussions and hearings, and diverse opinions from industry, civil society, and the youth were incorporated in this Strategy.

2. Korea's 2050 Vision

Our 2050 Vision

Under the principle of contributing to global climate action, laying foundation for sustainable and carbon-neutral society, and encouraging actions at all levels of stakeholders, Korea's 2050 Vision is established as follows:

> The Republic of Korea moves towards the goal of carbon neutrality by 2050.
>
> The Korean New Deal will serve as a stepping stone to reach carbon neutrality by 2050. Korea will harness green innovations and advanced digital technologies to create synergies between the Green New Deal and the Digital New Deal, the two pillars of the Korean New Deal. Korea will also take decisive action especially in supporting and investing in the development of innovative climate technologies to achieve carbon neutrality by 2050.
>
> Tackling climate change requires global efforts and collective engagement. Korea will lead by example to help the international community jointly make efforts to reach carbon neutrality by 2050.

1) Office for Government Policy Coordination; Ministry of Environment; Ministry of Economy and Finance; Ministry of Science and ICT; Ministry of Trade, Industry and Energy; Ministry of Foreign Affairs; Ministry of the Interior and Safety; Ministry of Agriculture, Food and Rural Affairs; Ministry of Land, Infrastructure and Transport; Ministry of Oceans and Fisheries; Ministry of Employment and Labor; Financial Services Commission; Korea Meteorological Administration; Korea Forest Service; and Rural Development Administration

Key elements of the 2050 Vision

The Strategy outlines the following five key elements that will guide Korea's policymaking, social transformation and technological innovations for its green transition.

❶ Expanding the use of clean power and hydrogen across all sectors

❷ Improving energy efficiency to a significant level

❸ Commercial deployment of carbon removal and other future technologies

❹ Scaling up the circular economy to improve industrial sustainability

❺ Enhancing carbon sinks

3. Visions and strategies by sector

Energy sector

In 2017, emissions from the energy sector accounted for 36% of the total emissions. Therefore, producing electricity in an eco-friendly manner without GHG emissions and using such green power in greater scope is the most essential mitigation strategy to achieve Korea's 2050 Vision.

To achieve carbon neutrality in the energy sector by 2050, clean and renewable energy, i.e., solar and wind, should become central power sources. However, renewable energy has volatility and intermittency issues, as it is sourced from the nature, and these issues need to be addressed for its wider deployment.

To this end, the Government will develop an accurate power demand and supply forecasting system and provide enhanced support for future innovative technologies, e.g., Energy Storage System (ESS) for reliable power supply, and hydrogen fuel cells for auxiliary power sources.

Korea plans to phase out coal power plants or convert them into LNG power plants. In addition, Carbon Capture, Utilization and Storage (CCUS) technology will be applied to coal-fired power plants to minimize GHG emissions.

Industry sector

The industry sector was estimated to be responsible for 37% of Korea's total GHG emissions in 2017. In the industry sector, we will continue to identify and foster future industries for growth while drawing up plans to strengthen industry competitiveness taking into account the global mitigation trends as well as the characteristics of each industry.

First and foremost, we need to achieve low-carbon transition in energy-intensive industries, i.e., steel, cement and petrochemicals production. Improving energy efficiency, transition towards circular economy, using low-carbon fuels and materials are possible strategies the industry sector can adopt. Measures to reduce F-gas emissions should be taken as well.

The Government and the industry sector will work together to scale up investment in applying new future technologies and developing technological innovations for the low-carbon transition of existing industrial processes. The prime example could be hydrogen reduction steelmaking, and Carbon Capture and Utilization for petrochemicals production. The Government will also work on building a robust institutional framework and infrastructure necessary for such technologies' deployment to industrial sites.

The Government plans to: i) facilitate the industry sector's transition to a high-value-added structure by combining ICT to the existing industries; ii) use regulatory measures in combination with incentives to improve energy efficiency; and iii) strengthen policies and technology developments for reusing wastes as resources that could dramatically reduce the use of raw materials and fuels for the purpose of efficient use of resources.

Transportation sector

Emissions from the transportation sector accounted for 14% of Korea's total emissions in 2017. The transportation sector's growth is largely being driven by the development of Industry 4.0 technologies with two dominating keywords: green and intelligence.

A modal shift is expected to take place from existing petroleum-based transportation system into future mobility featuring eco-friendly and autonomous vehicles. The Government will scale up its support for future mobility for its enhanced competitiveness and take policies in conjunction with fuel efficiency regulations to promote the use of low-carbon fuels.

The Government plans to: i) promote the use of public transportation; ii) expand shared mobility; iii) build systems for traffic demand management and intelligent transportation; iv) reduce energy consumption by promoting commercial use of autonomous vehicles; and v) promote the modal shift from road to rail or shipping, the low-carbon modes of transportation.

Building sector

The building sector was estimated to emit 7% of the total national emissions in 2017. Minimizing the energy use in the building sector, while maximizing the energy efficiency and supplying low-carbon energy, is the most cost-effective mitigation option that can reduce the energy cost and GHG emissions at the same time.

The Government plans to use a combination of regulatory measures and incentives in two-track approaches for: i) newly-built buildings and ii) old buildings. Starting from 2020, all new public buildings to be built will be subject to the zero-energy building standards, and from 2030, all new public and private buildings (with gross floor area of 5 million ㎡ or larger) will be subject to the standards. Old buildings, if they adopt green remodeling solutions, will be eligible for government incentives such as tax cuts and grants for interest expenses.

Along with improving energy efficiency, using low-carbon energy sources is another important mitigation strategy. Wall-mounted solar panels could contribute to decarbonizing power generation within buildings. Geothermal energy, hydro power and waste heat from power generation and incineration could replace fossil fuels used for heating/cooling of buildings. Improving energy efficiency and enabling passive and active houses is the core strategy to achieve the building sector's 2050 vision.

Waste sector

Emissions from the waste sector in 2017 took up 2.4% of Korea's total GHG emissions. It is important to maximize resource efficiency while minimizing resource inputs throughout the entire product lifecycle – from the extraction of natural resources, to production, distribution and consumption of products, to recycling and disposal of their waste – and creating a virtuous cycle where resources are reused and recycled repeatedly. This circular system will fundamentally reduce the amount of wastes generated at source.

The waste sector's strategy seeks to identify ways to convert wastes into useful materials and reuse them as energy sources. Any unrecycled wastes left should be disposed of in an eco-friendly manner. Plastics are one of the most serious problems in this sector that should be dealt with urgently, and measures to phase out plastics need to be established for a plastic-free society.

Farming sector

The agriculture, livestock farming and fisheries sector (collectively referred to as "farming sector") contributed 3.4% (including emissions from using energy) to the total GHG

emissions in Korea in 2017. GHG emissions from the farming sector mostly come from the biological reactions taking place from food production processes. Therefore, it is impossible to remove the sector's entire GHG emissions, but still there are many mitigation technologies available for use.

ICT-enabled smart farming could minimize inputs (i.e., energy sources, fertilizers, water, etc.), and farm automation could further improve productivity. Therefore, the Government plans to scale up the deployment of smart technologies on farms. To reduce GHG emissions originating from crop cultivation and livestock farming, it is essential to develop and deploy low-carbon farming practices and replace fossil fuels used on farms with clean energy sources.

Carbon sinks

In 2017, CO_2 removals by forests and other carbon sinks recorded 45.7 million ton CO_2eq, offsetting 7.4% of the energy sector's CO_2 emissions. However, when forests age, their net growth volume declines rapidly, driving down carbon removals as well. Considering the current state of forests and timber production plans, carbon removal is estimated to decrease by 30% from the current level by 2050. Innovative forest management, therefore, is a key to improving the aging forest structure, promoting the use of wood products/timber and increasing carbon stocks. The Government plans to increase carbon sinks by creating urban green spaces for recreational use, restoring degraded forestlands and tree-planting in underutilized lands. The Government will continue its forest management to maintain the forest carbon removals at the highest level possible by changing tree species and implementing programs to keep the forests healthy.

4. Innovating implementation base

To achieve carbon neutrality by 2050, we need a nationwide transformation that is supported by robust and sustainable institutional framework.

The Government will align its climate and energy policies to create synergies between them and consider climate change impacts when establishing fiscal policy directions and values. The Government will also aim to build a carbon pricing mechanism that could internalize climate and environmental externalities and encourage economic actors to reduce emissions, with public sector taking leadership towards carbon-neutrality transition.

To translate the awareness on climate change into people's concrete action, we will enhance our public outreach and education functions in collaboration with local communities. For our journey towards the 2050 carbon neutrality, a social conflict management system will be built to ensure a just transition for all.

In addition, green finance strategies will be laid out to change the course of our economy into a greener direction. A proactive approach will be key to ensure that policies are closely integrated to promote technological convergence and scale up R&D for innovations in order to move towards a carbon-neutral society by 2050.

5. Way forward

The 2050 carbon neutrality is a mission that should be pursued in a robust and consistent manner for the next 30 years. After presenting this Strategy, the Government will build a stronger governance structure, including by establishing the Presidential 2050 Carbon Neutrality Committee for systematic implementation of the Strategy and take necessary next steps to achieve the 2050 carbon neutrality.

2050 Carbon Neutral Strategy of the Republic of Korea

towards a sustainable and green society

Chapter 1

Introduction & Background

1. Why we should act now

1.1 Signs of climate change

Extreme weather events

In October 2018, the IPCC Special Report on Global Warming of 1.5°C released its finding that human activities are estimated to have caused approximately 1.0°C of global warming above the 1850-1900 period, with a likely range of 0.8-1.2°C as of 2017. The report has also found that estimated anthropogenic global warming is currently increasing at 0.2°C per decade and global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate.

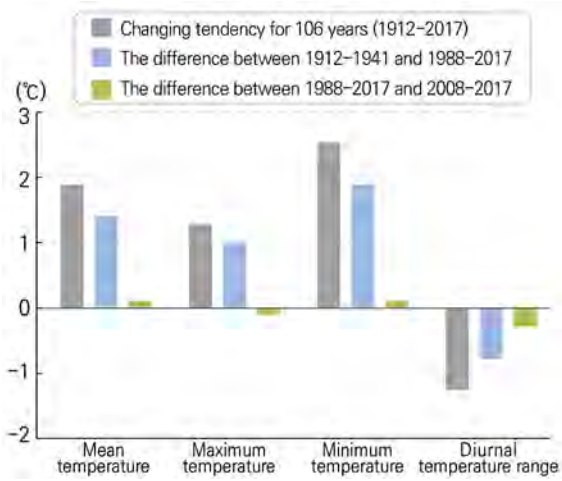
Extreme weather events are not unusual anymore. They can be experienced in many parts of the world. In June 2019, Europe saw its average temperature climb up to 25-29°C, 7-9°C up from the average year. Other regions also reported record-high summer temperatures in recent years. In 2018, the U.S. and Canada experienced the most severe cold waves and snowstorms in 100 years while massive wildfires on an unprecedented scale hit Australia and the Amazon rainforest.

Climate change impacts in Korea

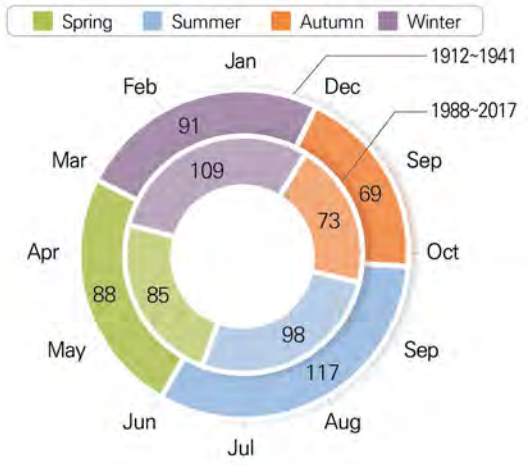
Korea is no exception in this trend. For the past century, the average temperature in Korea has risen 1.8°C, which is higher than the global average (0.8-1.2°C). Annual rainfall has also increased by nearly 160 mm. The average temperature for the past 30 years in Korea has soared 1.4°C, indicating climate change has been exacerbated. Rainfall intensity is also showing a polarizing trend of more heavy rain events and less moderate-intensity rain. A comparison between 30-year blocks, 1912-1941 and 1988-2017, demonstrates a growing trend of longer summers and shorter winters.

[Figure 1-1] Signs of climate change in Korea

Changing temperatures in Korea (1912~2017)



Changing lengths of seasons in Korea



Source Climate Change on the Korean Peninsula for the past 100 years(National Institute of Meteorological Sciences, 2018)

Projecting future climate in Korea

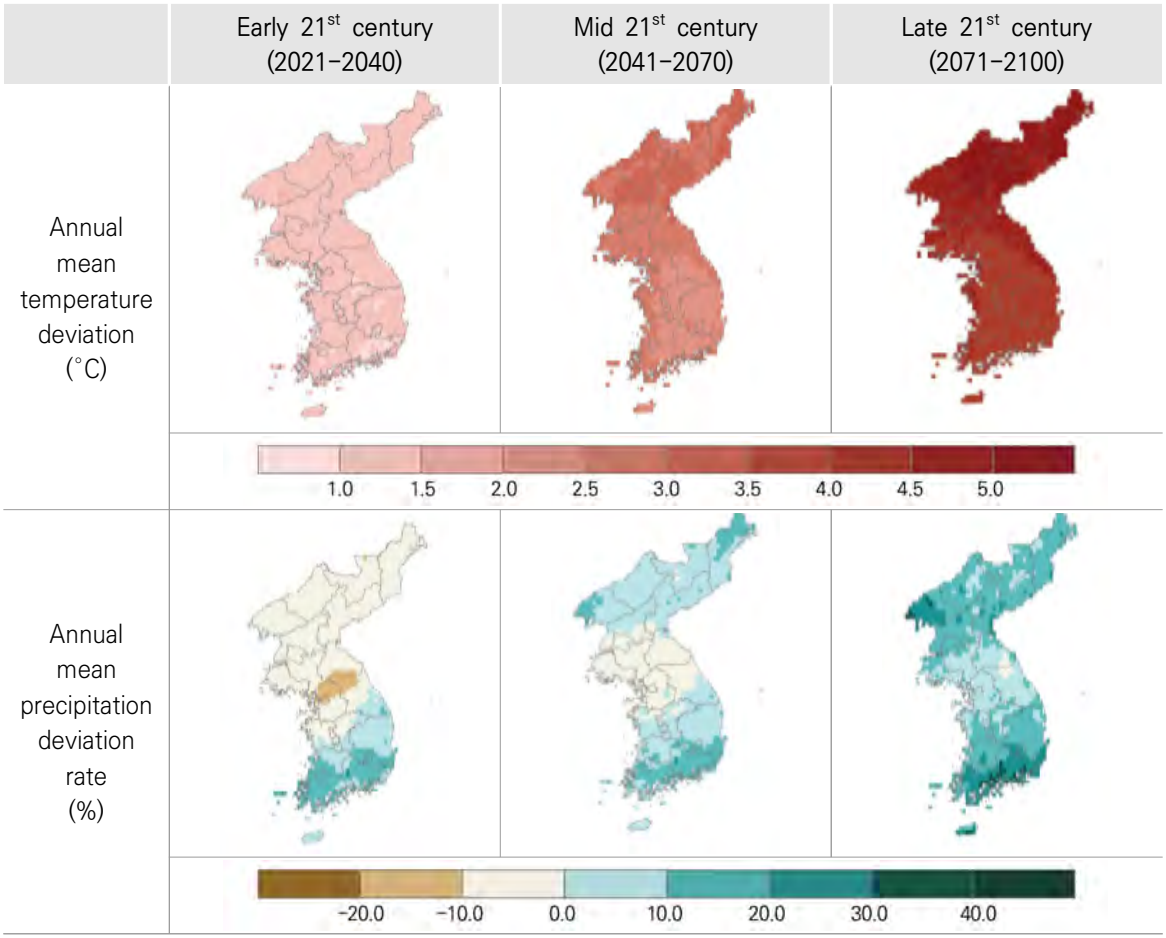
The recent reports by the IPCC[2] projected that the increase of global mean surface temperature by the end of the 21st century (2081-2100) is likely to be in the range of 0.3-4.8°C under its RCPs[3]. For the same period, the sea level rise is predicted to be in the range of 0.26-0.92 m. Based on the IPCC report and its scenarios, the Korea Meteorological Administration has projected the future climate of the Korean Peninsula in the second half of the 21st century. The projection indicates the pace of warming on the peninsula is expected to be faster than the global projection suggested in the IPCC report.

When RCP2.6 is applied to the Korean Peninsula, the temperature and precipitation increases are likely to be 1.8°C and 5.5%, respectively. RCP8.5 suggests that the temperature and precipitation on the Korean Peninsula will rise by 4.7°C and 13.1%, respectively. The subtropical climate zone, previously located only on the South Sea shore, is expected to expand and move northward. Extreme heat indicators, such as days of heatwaves and tropical nights, are predicted to rise while indicators for cold weather, such as days of cold waves, freezes, and frosts, are projected to decline.

2) IPCC Fifth Assessment Report (2014), Special Report on the Ocean and Cryosphere in a Changing Climate (2019)

3) Representative Concentration Pathways (RCPs) are scenarios that include time series of emissions and concentrations of the full suite of greenhouse gases (GHGs) and aerosols and chemically active gases, as well as land use/land cover.

[Figure 1-2] Future climate projection on the Korean Peninsula in comparison with average values between 1981 and 2010(applying RCP 8.5)



Source Korea Climate Change Report (Korea Meteorological Administration, 2018)

1.2 How the Paris Agreement was conceived

Limitations of the Kyoto Protocol

Recognizing the urgency of the climate change issue, the international community came together and adopted the Kyoto Protocol in December 1997, which later came into effect in February 2005. The Protocol, an implementing arm of the 1992 United Nations Framework Convention on Climate Change, has put the obligations to reduce GHG emissions on developed countries. Currently, there are 192 Parties to the Protocol, and Korea has become a Party as of 25 September 1998.

Despite such achievements, the Protocol had clear limitations: i) some developed countries refused to ratify the Protocol or withdrew from it; ii) developing countries were not obligated to reduce emissions at all; and iii) the Protocol had limited commitment periods, and its

consistency after that periods was uncertain. Due to these limitations, the countries decided to establish a new climate regime.

Adoption of the Paris Agreement

After 15 rounds of long-term negotiations since 2012, the Paris Agreement, joined by developing and developed countries, was adopted in 2015. After the adoption, the international community swiftly acted together, and the Agreement came into force as of 4 November 2016. Korea ratified the agreement on 3 November 2016.

Features of the Paris Agreement

The goal of the Paris Agreement is to hold the increase in the global average temperature to well below 2°C and pursue efforts to limit the increase to 1.5°C above pre-industrial levels. The Paris Agreement includes adaptation as an important element and lays out the essential means of implementations such as finance, technology and capacity building, to help developing countries achieve mitigation and adaptation targets.

The Paris Agreement requires all Parties to determine their own Nationally Determined Contributions (NDCs), including GHG emissions reduction targets and implement them ensuring transparency. Each Party shall communicate an NDC every five years in consideration of the goals of the Agreement. Each Party's successive NDC will represent a progression beyond the Party's then current NDC.

Parties shall report the national greenhouse gas inventory and information on mitigation policies and support through the transparency framework to the United Nations. The global stocktake continuously reviews global emissions levels, adaptation efforts, implementation, financial support, and the adequacy of the Parties' NDCs for achieving the goals of the Agreement.

1.3 Adoption of the IPCC Special Report on 1.5°C

In October 2018, Korea hosted the 48th session of the Intergovernmental Panel on Climate Change in Songdo, Incheon, where the *IPCC Special Report on Global Warming of 1.5°C* was approved after intense discussion. The IPCC report was prepared from the request of the UNFCCC to provide solid scientific evidence for the 1.5°C goal, the target agreed upon at the time of adopting the Paris Agreement.

Conditions to meet the 1.5°C target

The IPCC wrote in the special report that limiting global warming to 1.5°C by 2100 would require rapid, far-reaching, and unprecedented transitions in all sectors of society. According to the report, utilizing global mean surface air temperature provides an estimate of the remaining carbon budget of 580 $GtCO_2$ for a 50% probability of limiting warming to 1.5°C, and 420 $GtCO_2$ for a 66% probability. Alternatively, using global mean surface temperature gives estimates of 770 and 570 $GtCO_2$, for probabilities of 50% and 66%, respectively. In model pathways indicated in the report, global net anthropogenic CO_2 emissions decline by about 45% from 2010 levels by 2030, reaching net zero around 2050. For limiting global warming to below 2°C, the report suggests that CO_2 emissions are projected to decline by about 25% by 2030 from the 2010 level and reach net zero around 2070.

The report specifies that the pathways that overshoot 1.5°C of global warming rely on CO_2 removal measures to return to below 1.5°C by 2100. However, the report also warns that the impacts of CO_2 removal measures, if deployed on a large scale, are still unproven and could have potential trade-offs with sustainable development.

<Table 1-1> Impacts at global warming of 1.5℃ vs. 2℃ increase

Types of impact	1.5℃	2℃
Natural and Human systems	High risk	Extremely high risk
Mid-latitude, Extreme hot days	3℃ increase	4℃ increase
High-latitude, Extreme cold nights	4.5℃ increase	6℃ increase
Coral reef loss	70-90%	99% or more
Climate/poverty-vulnerable populations	If 2℃ rises, the vulnerable populations could increase by up to hundreds of millions by 2050	
Populations under water stress	If 2℃ rises, the populations under water stress could increase by up to 50%.	
Risks of large scale singular events	Moderate	Moderate - High
Sea level rise	0.26-0.77m	0.3-0.93m
Frequency of sea ice-free Arctic Ocean during summer	Once every 100 years	Once every 10 years

1.4 Global response

Time for Action

"Action" was the key word for global climate response throughout the year of 2019. The United Nations held the Climate Action Summit in New York in September 2019, and the main theme of COP25 in the same year was "Time for Action." Globally, there was widespread recognition that now is the time that countries should come together to take climate action.

The youth, those who will be one of the most affected by climate change, have already started their action. Over 1 million young people from nearly 100 countries participated in "school strikes for climate" to demand action from political leaders. In Korea, prior to the Climate Action Summit, youths and the activists from civil society, academia, religious groups came together to call for urgent action.

International community's movement

The international community is answering the call from the youth. The UN Secretary-General also stressed that at the 11th Petersburg Climate Dialogue held in April 2020, all countries should commit to carbon neutrality by 2050 to limit the global temperature rise to 1.5°C.

Fossil fuel is rapidly giving way to renewable energy while coal power is being phased out. Green cars powered by alternative fuels are widely deployed across markets, and green investments are scaling up. Since the Paris Agreement was adopted in 2015, 65.7% (178GW) of the global investment in energy facilities has been focused on renewables, most notably photovoltaics and wind power. Coal power is increasingly recognized as a stranded asset worldwide. Global demand for new coal-fired power plants has been in steep decline since its peak in 2015[4]. The EU, Canada and many other countries are declaring that they are moving away from coal power generation.

Financial investments are becoming greener as well. Along with the OECD guideline[5] on export credits relating to coal-fired power generation projects, the Financial Stability Board[6], upon the G20's request, launched a Taskforce on Climate-related Financial Disclosures (TCFD) that recommends all companies including financial firms disclose information on climate change-related financial risks in a transparent manner. The recommendation is based on the scenario of achieving the Paris Agreement's 2°C target. The Ministry of Environment of Korea has declared its support for the TCFD in May 2020.

4) Global coal power generation capacity changes: 88GW (2015) → 39GW (2016) → 33GW (2017) → 22GW (2018)

5) *The Coal-fired Electricity Generation Sector Understanding of the Arrangement on Officially Supported Export Credits*

6) The Financial Stability Board is an international body that oversees the monitoring of financial reform implementation to achieve stability in the global financial system. The board is joined by G20 economies.

1.5 Why we should take climate action

From climate change to climate emergency

Climate change-induced natural disasters in all forms – heatwaves, snowstorms, typhoons, wildfires, for example – are taking place globally. The catastrophic disasters are wreaking havoc on human life in various forms: food scarcity, floods and diseases. The impacts of climate change are palpable now, which means it is as damaging for us as it will be for our children, and therefore, immediate action needs to be taken.

Unfortunately, however, our time is limited. We will have only 10 years left to achieve the 1.5°C target given the remaining carbon budget indicated in the IPCC Special Report.

Cost and benefit of climate action

The key to reducing GHG emissions and responding to climate change is to use less fossil fuel. Inevitably, the economy and industry will suffer a short-term impact from it. However, the losses and damages from inaction could be far greater than the short-term economic and industrial impact.

In its working paper, the IMF warned[7] that a persistent increase in average global temperature by 0.04°C, in the absence of mitigation policies, reduces world real GDP per capita by more than 7% by 2100. On the other hand, abiding by the Paris Agreement, thereby limiting the temperature increase to 0.01°C per annum reduces the loss substantially to 1.07%. According to the

Financial Stability Board, the value at risk to manageable assets from climate change is estimated at about USD 4 trillion[8]. The International Renewable Energy Agency also warns that slow progress of emissions mitigation will result in stranded assets worth nearly USD 12 trillion[9].

For Korea, implementing mitigation policies has a clear co-benefit, which is improved air quality. GHG emissions and air pollutants originate from the same source – burning fossil fuels– therefore, mitigation policies to reduce GHG emissions, when implemented, have a huge co-benefit of reducing airborne particulate matters.

7) Matthew K. Kahn, et al., IMF Working Paper, 'Long-Term Macroeconomic Effects of Climate Change: A Cross-Country Analysis', International Monetary Fund, October 2019

8) Economist Intelligence Unit, The Cost of Inaction: Recognizing the Value at Risk from Climate Change, 2015

9) International Renewable Energy Agency, Global Energy Transformation: A Roadmap to 2050, 2019

2. Background of establishing Korea's long-term strategy

2.1 Objectives of the Paris Agreement

The Paris Agreement calls for all Parties to hold the increase in the global average temperature to well below 2°C and pursue efforts to limit the increase to 1.5°C above pre-industrial levels. The Agreement further recommends that all Parties strive to formulate and communicate Long-term low greenhouse gas Emission Development Strategies (LEDS) by 2020 as long-term vision for responding to climate change. As a Party to the Paris Agreement, Korea decided to answer this global call for climate action by developing its LEDS. In September 2019, President Moon Jae-in attended the UN Climate Action Summit in New York to indicate Korea's commitment to presenting the Strategy to the international community by the end of 2020.

2.2 Why Korea needs its long-term strategy

Recalibrating national climate policy

As a Party to the Paris Agreement, Korea will update and communicate its NDC that includes its updated 2030 GHG emissions reduction target to the UNFCCC Secretariat by the end of 2020. Korea's LEDS is based on this updated NDC. The Strategy includes our 2050 Vision that will determine the general directions to which our climate policy should be headed by 2050. Establishing the Strategy demanded extensive analyses on the entire range of our current mitigation policies. It required a closer look at where emissions come from, how energy is supplied, and what mitigation technologies are available. The works of preparing the Strategy also provided a valuable opportunity, most importantly, to lay out our 2050 Vision and sectoral strategies after reaching public consensus on them.

Establishing a national vision for a carbon-neutral society

Realizing a carbon-neutral society is a vision that can be achieved only when shared with and understood by all members of society. The Strategy outlines the 2050 Vision that harmonizes Korea's economic, social, environmental and energy policies and sets out a

common direction into which we all should be headed to achieve the Vision. The Strategy also proposes solutions to address potential challenges that could pose obstacles in that path towards a carbon-neutral future.

We understand that now we need a long-term vision at the national level and consistent policies to achieve that vision to turn the carbon neutrality expectations shared across government, industry, and people into concrete action. A clear national vision will serve as a beacon for people to act and for businesses and other stakeholders to make sensible investment decisions for the future. The Strategy will send a strong signal for Korea's climate policies.

The 2050 Vision in the Strategy will help develop a shared understanding that a fossil fuel-dependent economy and society will no longer be sustainable in the future. The Vision will open up broader discussions around fair burden-sharing necessary to achieve the ultimate goal of sustainable economic and social prosperity where economic and environmental benefits go hand in hand.

Using the Carbon Neutral Strategy as a driver for future growth

Korea's industries import most of their energy sources from overseas. Most prominent energy-intensive industries – steelmaking, petrochemicals and semiconductors production – are the backbones of Korea's industrial growth. Cutting down fossil fuel use, under such circumstances, clearly poses a huge challenge for Korea. However, for the future generations' survival and their sustainable future, the task of reducing GHG emissions is a global challenge that must be met, and this challenge should be considered as an opportunity for future growth.

Korea's highly developed ICT and leading technologies of electric vehicles (EVs) and Energy Storage System (ESS) provide an enabling environment for a convergence between green innovations and Industry 4.0 technologies. Such convergence is expected to give rise to a new wave of the low-carbon industry that will replace conventional energy-intensive industry.

The Strategy will present meaningful opportunities for us to start recognizing that moving towards carbon neutrality is a formula for future growth.

3. How Korea's long-term strategy was developed

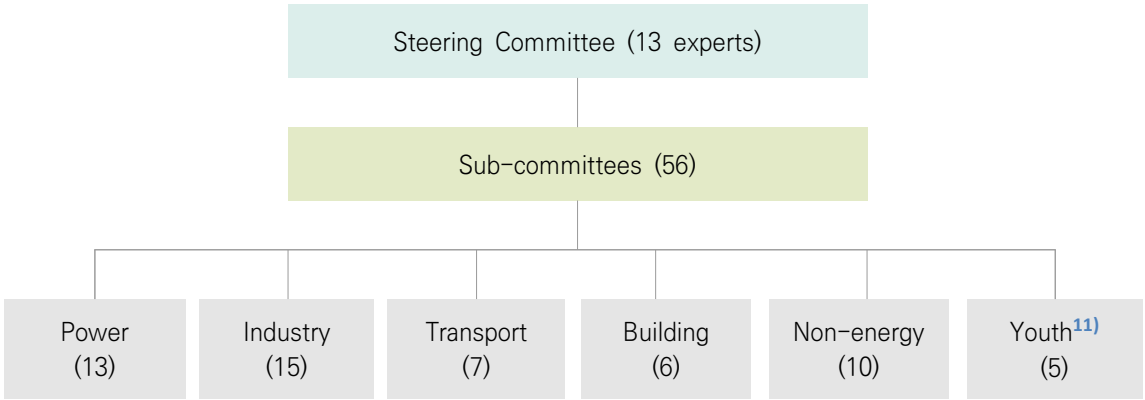
3.1 The 2050 Low-carbon Vision Forum

Operating the 2050 Low-carbon Vision Forum

Implementing the Strategy requires a comprehensive level of transformation across the economy, industry, energy, environment, technology and people's daily lives. Considering the far-reaching scope of the transformation, we have established the 2050 Low-carbon Vision Forum participated by academia, industry, and civil society from the initial stage of developing the Strategy. What was discussed at the Forum by experts from various fields has provided significant inputs for the preparation of the Strategy.

The Forum was attended by 69 experts from seven sub-committees, each recommended by their respective professional fields. The Forum's technical working group comprised of experts from national research institutes and thinktanks[10] supported the Forum's decision-making process by offering assessments and analytics of different emissions reduction scenarios.

[Figure 1-3] Governance of the forum



10) A total of 34 representatives from 22 institutes including the Greenhouse Gas Inventory and Research Center, Korea Energy Economics Institute, Korea Institute for Industrial Economics and Trade, and Korea Transport Institute, participated.

11) The sub-committee on youths was included considering the future orientation of the Strategy. A total of five young representatives in the sub-committee presented their vision for 2050, which was incorporated into the Strategy.

Projections for population growth, GDP increase and industrial structure by 2050 were used to estimate the Business-As-Usual (BAU) level in 2050. Against this BAU scenario, a multiple number of scenarios suggesting a different level of targets and visions were produced and reviewed by the Forum. In the process, all circumstances affecting Korea' mitigation efforts – policies, institutional frameworks and government budgets – were considered in conjunction with the feasibilities of available mitigation technologies and international trends.

Implications of the Forum's proposal

The Forum drafted a proposal that contained the result of intensive analyses and discussions by its members, who are the leading climate and energy experts in Korea. The Forum's proposal become a basis for the Government's followed work of collecting wider social opinions and establishing the Strategy.

3.2 Social dialogue

Online survey

An open public online survey was conducted for the period of two months (June-July 2020) to promote the LEDS. The survey responses were supplemented with a field research conducted by a professional polling agency to understand what the general public and business sector expect for the LEDS. Nearly 3,000 people answered the online questionnaires, which comprised 58 questions on the recognition of climate change, intention to take part in climate action, and priority of climate policies. The results show that the majority of respondents were recognizing the climate crisis and agreed on the need to consider 2050 carbon neutrality. Most respondents believed that carbon neutrality by 2050 requires consideration of its economic and social impacts[12)].

12) On climate risk, 91.5% responded that climate change is serious and 96.8% thought climate change is affecting their daily life to a significant extent. On 2050 climate neutrality, 92.5% answered that Korea needs to consider 2050 carbon neutrality. The respondents chose economic and social impacts (58.9%), the goals of the Paris Agreement (42.2%), and LEDS targets of other countries (33.9%) as major concerns that need to be considered in considering carbon neutrality.

Expert consultation

Expert advice was collected to set up visions and key tasks for a low-carbon transition through a series of debate sessions participated by professionals from the industry sector, civil society, and academia. Each of the five debate sessions held in July 2020 was respectively themed with green mobility, low-carbon future technologies, industrial innovation, renewable energy, and innovative national approaches for climate actions.

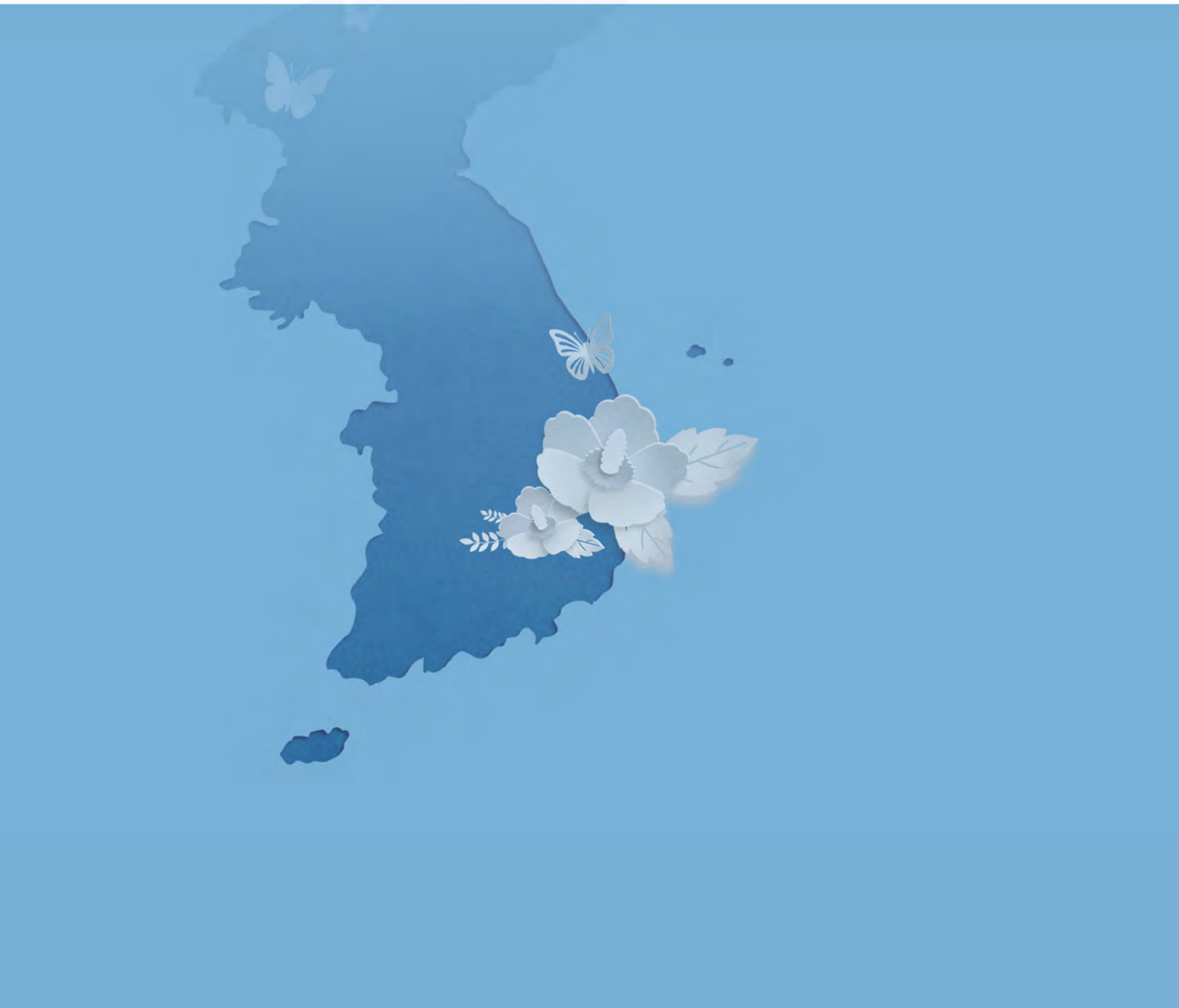
The experts shared different perspectives and ideas on policy obstacles and technical barriers of the transition to a low carbon society and offered possible solutions, which were incorporated in drafting this Strategy.

Public Discussion

An open public forum was held on 17 October 2020 to listen to people's views and ideas and encourage them to play as the main actor in climate change response.

Under the theme of "Challenges and Tasks of Establishing 2050 LEDS for the Transition towards Carbon Neutrality," the forum addressed five key areas of energy, industry, building, transport, and social transition. The keynote presentations were delivered under the titles of "IPCC Assessment of Climate Change," and "Features of 2050 LEDS and Global Trends." Expert presentations were delivered, followed by Q&A sessions.

The forum's participants who had been invited based on the consideration of regional, gender, and age mix were asked to answer a questionnaire on the vision of Korea's LEDS. The results showed that 91% of the participants agreed on the pursuit of carbon neutrality by 2050, and 81% were willing to bear their share of the cost for decarbonization. The result of the forum and the survey were incorporated in drafting Korea's 2050 Vision and this Strategy.



Chapter 2

Korea's Climate Policies

1. Greenhouse gas emissions

1.1 Current Status

Total emissions

In 2017, the total GHG emissions in Korea were 709.1 million tCO_2eq of GHGs[13], which is 2.4% up from the previous year (692.6 million tCO_2eq) and 142.7% up from 1990 level (292.2 million tCO_2eq). The year-on-year emissions trend from 1990 to 1997 presented a sharp growth with average annual increase at 8.1%, having an exception in 1998 when the GHG emissions decreased by 14.1% year-on-year as the national economy was in the aftermath of the 1997 Asian financial crisis.

From the 2000s as the economy started rebounding, both the emissions level and GDP began to rise. In the 2000s, the emissions growth has slowed down significantly, and since 2013[14], has maintained a stable level without much fluctuation.

<Table 2-1> Korea's GHG emissions trend

(Unit: million ton CO_2eq)

Sector		1990	1995	2000	2005	2010	2013	2014	2015	2016	2017
Gross emissions (excl. LULUCF)	Emissions	292.2	435.9	503.1	561.8	657.6	697.0	691.5	692.3	692.6	709.1
	Percentage (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	YOY change (%)	-	7.9	7.1	0.8	10.0	1.4	-0.8	0.1	0.03	2.4
Net emissions (incl. LULUCF)	Emissions	254.4	405.0	444.8	507.7	603.8	652.8	649.3	649.9	648.7	667.6
	Percentage (%)	87.1	92.9	88.4	90.4	91.8	93.7	93.9	93.9	93.7	94.1
	YOY change (%)	-	9.1	7.3	1.3	11.5	2.2	-0.5	0.1	-0.2	2.9
Energy	Emissions	240.4	352.2	411.8	468.9	566.1	605.1	597.5	600.8	602.7	615.8
	Percentage (%)	82.3	80.8	81.9	83.5	86.1	86.8	86.4	86.8	87.0	86.8
	YOY change (%)	-	7.4	7.7	1.9	10.3	1.5	-1.3	0.6	0.3	2.2
Industrial process	Emissions	20.4	45.2	51.3	55.7	54.7	54.8	57.3	54.4	52.8	56.0
	Percentage (%)	7.0	10.4	10.2	9.9	8.3	7.9	8.3	7.9	7.6	7.9
	YOY change (%)	-	15.6	5.1	-5.6	13.5	1.1	4.6	-5.1	-2.8	6.0

13) The total emissions are the sum of the emissions from energy, industrial process, agriculture, and waste sectors except the emissions and removals from LULUCF.

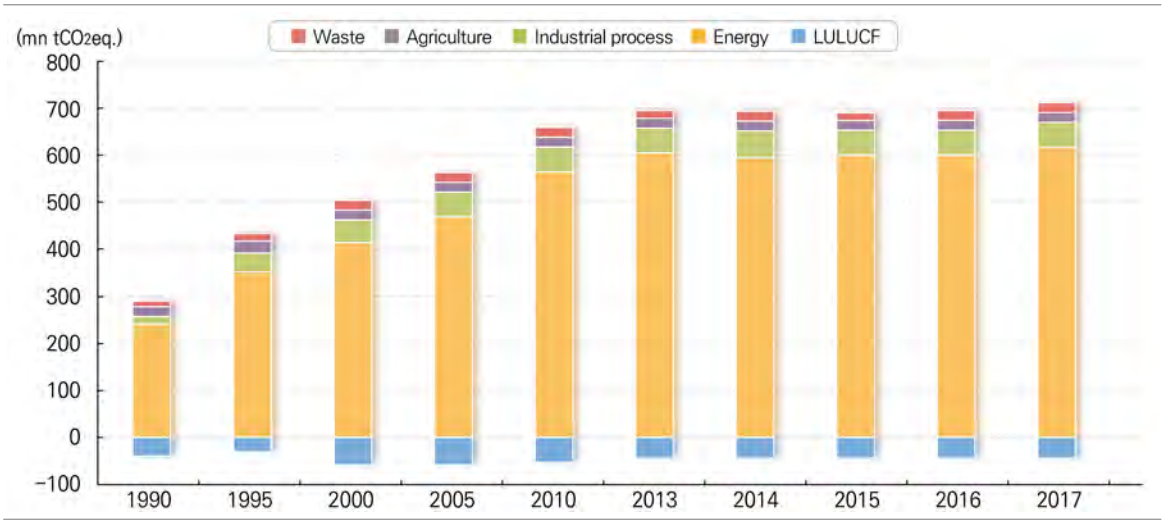
14) A series of policy measures to cut emissions came into effect with the enforcement of the Framework Act on Low Carbon Green Growth (enacted on 13 Jan 2010) and contributed to slowing Korea's emissions growth. Promoting clean energy sources and adopting demand side approaches to the energy sector were among the measures taken.

Sector		1990	1995	2000	2005	2010	2013	2014	2015	2016	2017
Agriculture	Emissions	21.0	22.8	21.2	20.5	21.7	21.2	21.3	20.8	20.5	20.4
	Percentage (%)	7.2	5.2	4.2	3.6	3.3	3.0	3.1	3.0	3.0	2.9
	YOY change (%)	-	1.1	-2.7	0.8	1.9	-0.2	0.5	-2.4	-1.5	-0.3
LULUCF	Emissions	-37.7	-30.9	-58.3	-54.0	-53.8	-44.2	-42.2	-42.4	-43.9	-41.6
	Percentage (%)	-12.9	-7.1	-11.6	-9.6	-8.2	-6.3	-6.1	-6.1	-6.3	-5.9
	YOY change (%)	-	-6.0	5.5	-3.7	-4.4	-9.1	-4.5	0.5	3.5	-5.3
Waste	Emissions	10.4	15.7	18.8	16.7	15.0	15.9	15.4	16.3	16.5	16.8
	Percentage (%)	3.6	3.6	3.7	3.0	2.3	2.3	2.2	2.4	2.4	2.4
	YOY change (%)	-	9.2	11.7	-5.5	-2.2	0.9	-3.2	6.1	1.1	2.0

※ YOY change: increase/decrease rate compared to the previous year (%)
Percentage of LULUCF: percentage of total net emissions in LULUCF sector to national total emissions in absolute value (%)

Source 2019 National GHG Emissions Inventory Report

[Figure 2-1] National GHG emissions and removals trend (1990-2017)



GHG emissions per GDP

Korea's GHG emissions per GDP has declined in general since the 1990s. Until 1997, GHG emissions grew at a pace comparable to the economic growth causing little change in the level of emissions per GDP. However, the emissions growth has been outpaced by the economic growth from 1998, which led to a continuous decline in emissions per GDP to date. Although this could represent a relative decoupling of emissions from economic growth[15], an absolute decoupling[16] has not been realized given that the emissions growth itself has not reversed into a decline.

15) In this Strategy, when GDP growth rate is higher than GHG emissions growth rate, we assume relative decoupling has been achieved.

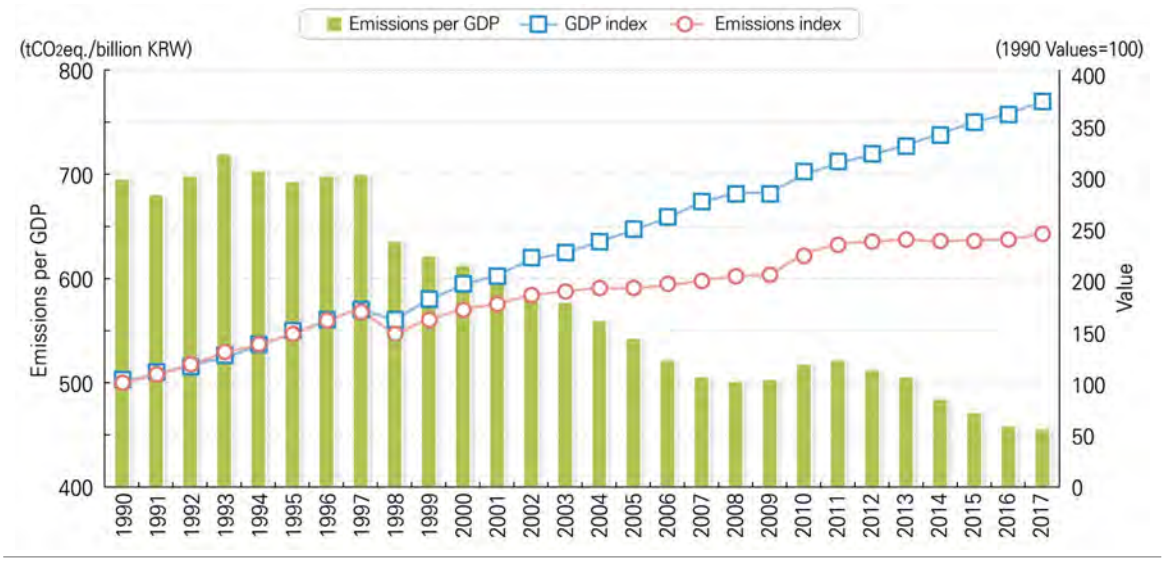
16) In this Strategy, when GHG emissions decrease while GDP increases, we assume absolute decoupling has been achieved.

<Table 2-2> Trend of GHG emissions per GDP

	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017
GHG emissions/GDP (tCO_2eq/billion KRW)	696	694	613	543	520	505	485	472	459	456
YOY change (%)		−1.5	−1.7	−3.0	3.3	−1.5	−4.0	−2.6	−2.8	−0.7
GHG emissions (million tCO_2eq)	292	436	503	562	658	697	691	692	693	709
YOY change (%)		7.9	7.1	0.8	10.0	1.4	−0.8	0.1	0.0	2.4
GDP (trillion KRW)	420	628	821	1,034	1,265	1,381	1,427	1,467	1,510	1,556
YOY change (%)		9.6	8.9	3.9	6.5	2.9	3.3	2.8	2.9	3.1

Source 2nd Basic Plan for Climate Change Response(Oct. 2019)

[Figure 2-2] GHG emissions per GDP (1990-2017)



1.2 Korea's emissions level in comparison

In 2016, Korea was estimated to be the 11th largest GHG emitter in the world[17]. The total emissions amounted to 5.7% of the emissions of China and 10.7% of the U.S., which are respectively world's first and second largest emitters.

However, having a high CO_2 emissions ratio from fuel combustion at 87% of the total GHG emissions, Korea's CO_2 emissions ranks 7th in the world and 4th among the OECD members following the U.S., Japan, and Germany.

17) The estimation was made based on the analysis of statistical data by UNFCCC. The data includes emissions from top 15 emitting countries as of 2016. For the Non-annex I states whose recent emissions data is not available, the CO_2 emissions percentage estimated by the World Resources Institute and International Energy Agency was used.

2. 2030 GHG emissions reduction target

2.1 Korea's NDC

Background

The Paris Agreement requires all Parties to prepare NDCs periodically. Following the decision of COP 19 held in Lima (1/CP.19), majority of the Parties submitted their INDCs in 2015, and as they ratified the Paris Agreement in 2016, their INDCs have been registered as NDCs. The decision of COP 21 held in Paris (1/CP.21) requests Parties to update or communicate their NDCs by 2020.

To implement its NDC that includes 2030 GHG emissions reduction target, Korea conducted analyses of reduction potentials in eight key sectors: power (electricity and heating), industry, transport, building, agriculture and livestock farming, wastes, public, and forestry. Based on the analyses, sectoral reduction targets were set, which were included in the 2030 Roadmap to Achieve National GHG Reduction Target (2030 Roadmap) formulated in 2016. After President Moon Jae-in took office, Korea updated the 2030 Roadmap and released the revision in 2018. The revision minimized the portion of the overseas reduction due to the uncertainty in its implementation. The Administration's energy transition plan including shutting down old coal power plants and increasing renewable energy target was also incorporated in the revision.

Conditions for mitigation

Since the beginning of the industrialization, Korea has maintained its export-led industry structure with manufacturing at the center. Manufacturing sector accounted for 32.1% of the GDP in 2017, and export dependency (export to GDP ratio) also remained high at 35.3%. Meanwhile, Korea is the world's 8th largest energy consumer, with its GDP ranking 12th in the world, and the amount of energy use is constantly growing. For the period from 2000 to 2017, Korea's final energy consumption increased by 53%; especially the industry sector which consumed 60% of the total energy use presented a 68% increase for the same period.

Energy intensive industries such as steel, petrochemical, automobile, and semiconductor are taking up the majority of the manufacturing sector. For this reason, despite achieving the world's highest-level energy efficiency in manufacturing[18], Korea's energy intensity index (primary energy consumption to GPD) has stagnated for years ranking 33rd[19] among OECD members in 2017.

<Table 2-3> Dependency on export and manufacturing sector

	1990	2000	2011	2012	2013	2014	2015	2016	2017
Export dependency (%)[1]	23.3	29.9	44.3	42.9	40.8	38.6	36.0	33.0	35.3
Manufacturing dependency (%)[2]	23.5	26.4	31.6	31.6	31.8	31.9	31.6	31.6	32.1

Source 1) Statistics Korea (Korea Customs Service), 2) Korea Institute for Industrial Economics and Trade

Climate condition is an important factor for renewable energy production. Located in the mid-latitude temperate climate zone, Korea has distinct four seasons with large seasonal differences in the amount of solar radiation[20], which complicates stable solar power supply all year round. In terms of wind power, it has been found that only 25% of onshore and 40% of offshore winds are usable for power generation[21].

2030 GHG reduction target

Korea's NDC target is to cut GHG emissions by 24.4% below 2017 level by 2030 (GHG emissions target by 2030 is set at 536 million tCO_2eq). To achieve this target, we will implement a set of reduction strategies for the sectors including power, industry, building and transportation and take additional measures including carbon sinks by forests and reduction from overseas projects.

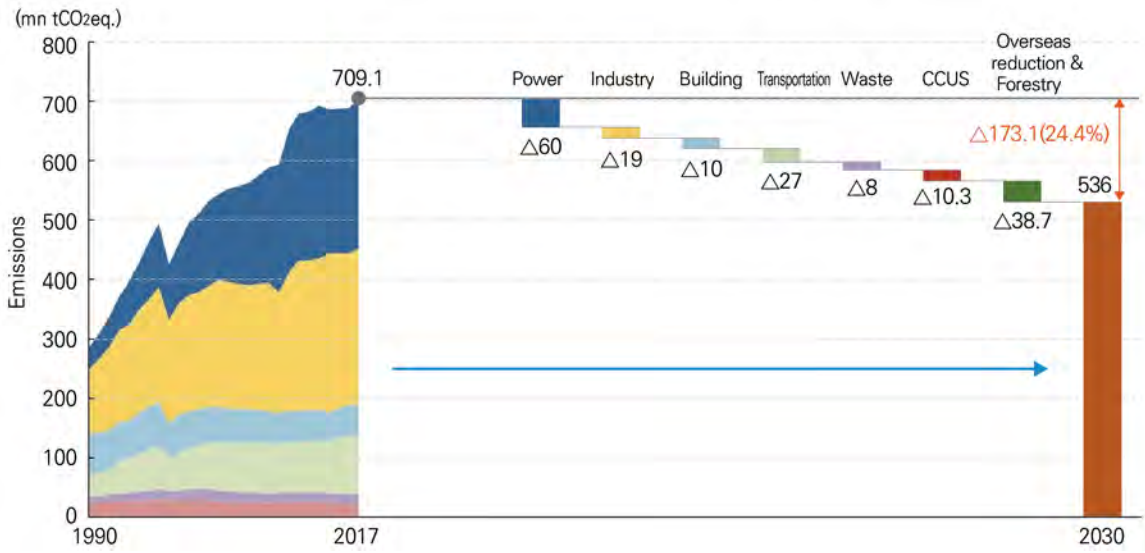
18) Manufacturing sector's energy efficiency data from major global agencies such as World Steel Association was used

19) Korea's energy consumption to GPD is 0.159 (TOE/1,000 USD), US at 0.123, Japan at 0.089, and the average of OECD member states at 0.105. (IEA, 2017)

20) Korea's solar radiation in each season compared to the annual average radiation: 20% higher in spring, 25% higher in summer, 12% lower in fall, and 33% lower in winter.

21) 3rd Biennial Update Report of the Republic of Korea (2019)

[Figure 2-3] 2030 GHG reduction targets[22)]



22) Emissions from power sector were divided based on each sector's electricity consumption and then distributed to each sector as indirect emissions.

3. Mitigation policies

3.1 Laws and institutions

Framework Act on Low Carbon Green Growth

Korea has enacted the Framework Act on Low Carbon Green Growth in 2010 with the objective of building the foundation for a low-carbon society and harnessing environmental technologies and green industry as a new growth engine for the national economy.

The Act prescribes the establishment and implementation of basic plans on green growth (National Green Growth Strategy), climate change (Basic Plan on Climate Change Response), and energy policies (Basic Energy Plan) on a five-year basis. These plans are required to be developed to meet the national GHG reduction target defined in the Enforcement Decree of the Act[23].

The Presidential Committee on Green Growth[24] composed of government officials and private experts deliberates and decides the polices to cope with climate change and energy transition.

<Table 2-4> Basic principles on climate and energy policies

Basic Principles for Coping with Climate Change	Basic Principles of Policies on Energy
① It shall recognize the seriousness of problems of climate change ensuing from global warming, cope with such problems comprehensively by putting together capacities of the State and citizens, and participate in global efforts actively. ② It shall establish the State's medium and long-term target for greenhouse gas emission reduction by analyzing costs of and benefits from the reduction of greenhouse gases in the economic aspect and taking domestic and overseas conditions into consideration and promote the reduction of greenhouse gases efficiently and systematically by introducing a cost-effective, reasonable regulation system based on pricing functions and market system.	① It shall recognize the seriousness of problems of climate change ensuing from global warming, cope with such problems comprehensively by putting together capacities of the State and citizens, and participate in global efforts actively. ② It shall establish the State's medium and long-term target for greenhouse gas emission reduction by analyzing costs of and benefits from the reduction of greenhouse gases in the economic aspect and taking domestic and overseas conditions into consideration and promote the reduction of greenhouse gases efficiently and systematically by introducing a cost-effective, reasonable regulation system based on pricing functions and market system.

23) Cutting GHG emissions 24.4% below 2017 levels (enforced in 31 Dec 2019)

24) The Presidential Committee on Green Growth is chaired by Prime Minister and composed of 43 committee members including 18 Minister-level government officials and 25 experts from private sector.

Basic Principles for Coping with Climate Change	Basic Principles of Policies on Energy
③ It shall develop and utilize high technology and convergence technology, such as technology for information and communications, nanotechnology, biotechnology, to reduce greenhouse gases drastically.	③ It shall develop and utilize high technology and convergence technology, such as technology for information and communications, nanotechnology, biotechnology, to reduce greenhouse gases drastically.
④ It shall enable to adopt various means for reduction autonomously by clarifying rights and obligations in connection with the greenhouse gas emission and allowing transactions of such rights and obligations in the market and shall be prepared for the international carbon market by boosting the domestic carbon market.	④ It shall enable to adopt various means for reduction autonomously by clarifying rights and obligations in connection with the greenhouse gas emission and allowing transactions of such rights and obligations in the market and shall be prepared for the international carbon market by boosting the domestic carbon market.

Emissions Trading Scheme

The emissions trading scheme (ETS) is a market-based mitigation tool in which the government allocates GHG emissions allowances (emissions cap) to businesses and have them trade the allowances freely in the market to dispose of the surplus or make up the deficit in their allocated allowances. An increasing number of economies are opting for this cost-effective[25] GHG reduction scheme using the market mechanism including the EU, Switzerland, and New Zealand.

In 2012, Korea enacted the Act on the Allocation and Trading of Greenhouse Gas Emission Permits which made the legal basis for the Korean ETS (K-ETS). Following a pilot stage, the Phase 1 of the K-ETS (2015-2017) was carried out having 252 enterprises[26] subject to the scheme.

After setting up the emissions cap in line with the national GHG reduction targets, the ratio of free allocation and auctioning is determined in consideration of characteristics of each business type. The allocation takes either grandfathering (GF)[27] or benchmarking (BM)[28] method.

25) The ETS incurs 44-68% lower cost than non-market based approaches, i.e., direct regulations on emissions (Samsung Economic Research Institute, 2009)

26) Enterprises emitting over 125,000 tCO_2eq/year or owning a plant that emits over 25,000 tCO_2eq/year.

27) Grandfathering method allocates allowances based on individual installations' historical emissions levels, making simple allocation possible. However, the method has been criticized for not being able to take into account emissions reduction efficiencies and resulting in more allowances allocated to large-emitters.

28) Benchmarking method allocates allowances based on emissions intensity of individual installations of the same business type. With this method, more allowances are allocated to installations with lower emissions as long as the installations' production outputs are the same.

During the Phase 1, all companies under the scheme were given allowances free of charge, and only three types of business were subject to BM-based allocation. Auctioning has come into play from the Phase 2 (2018-2020) targeting selected business categories, and BM application has also been extended to seven business types.

To ensure a high-level of flexibility in the carbon market, external credits are recognized and auctioning is operated on a regular basis. The allowances were traded at around KRW 8,000 during the early stage of the K-ETS, but the price has gradually increased up to KRW 20,000 as of October 2020.

[Figure 2-4] Carbon price trend

In preparation for the beginning of NDC implementation under the Paris Agreement from 2021, the Phase 3 Allocation Plan (2021–2025) was prepared in December 2019 with the aim of contributing to the achievement of the 2030 national GHG reduction target. The key elements of the Basic Plan are as in the Table 2-5.

<Table 2-5> Work plan of Phase 3 K-ETS

Allocation	• Set the total emissions target in accordance with the 2030 national GHG emissions target in the NDC • Increase the share of auctioning to 10% and raise the number of business types subject to BM method from 7 to 12 • Change the unit of allowance calculation from “installations” to “business sites”

Market	• Allow other participants – financial institutions – to trade on the market • Maintain market liquidity by supplying or retrieving liquidity reserve • Introduce derivatives and allow futures trading on the Exchange
Support for Industry	• Use revenues from auctioning of allowances to invest in companies' eco-friendly practices • Survey mitigation technologies from major businesses and share the ones with proven mitigation effects
International Market Mechanism	• Use overseas carbon offsets to earn carbon credits in compliance with the Paris Agreement

GHG target management system

The Target Management System (TMS) is a direct regulation program managing the emissions from the small- and medium-sized enterprises whose emissions are relatively lower and not covered by the K-ETS. A company subject to the TMS are required to make voluntary efforts not to exceed a cap of GHG emissions or energy consumption which has been set by the Government in consultation with the company. If a company fails to achieve the target, it will be given an improvement order or subject to penalty.

Since first introduced in 2010, the emissions and energy consumption levels above which businesses are subject to the TMS have been lowered three times. The current thresholds for an entity and a business site are, based on latest three-year average GHG emissions, 50,000 tons CO_2eq(energy consumption of 200TJ) and 15,000 tons CO_2eq (energy consumption of 80TJ) respectively[29].

<Table 2-6> Changes in threshold of TMS

Index	Until 2011		From 2012		From 2014	
	Entity	Business site	Entity	Business site	Entity	Business site
GHG emissions (tCO_2eq)	125,000	25,000	87,500	20,000	50,000	15,000
Energy consumption (TJ)	500	100	350	90	200	80

Source Guideline for the operation of GHG/energy TMS

29) Any enterprise that has enrolled in the ETS is excluded from the TMS.

3.2 Mitigation policy measures

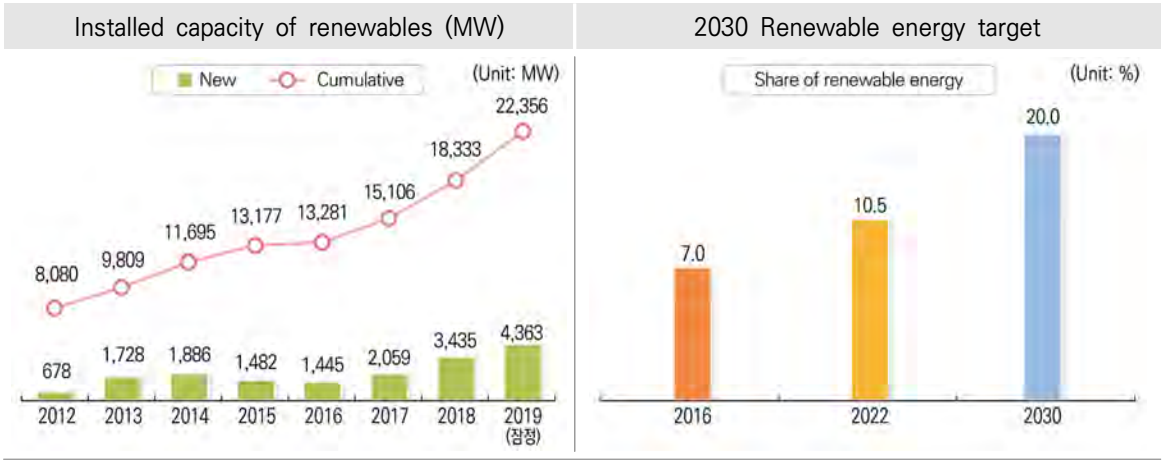
Transition to green energy

Since the launch of the Moon Jae-in administration, Korea has been spurring the energy transition by reducing coal and increasing renewables in its energy portfolio. The Government decided to suspend the construction of new coal-fired power stations and shut down 14 coal power plants which are 30-year old or older. (Four plants have permanently ceased operation to date.) The 9th Basic Plan for Power Supply and Demand that contains further actions to shut down additional coal-fired power plants has been established to achieve the NDC.

We have also made considerable progress in switching to renewable energy sources. The Renewable Energy 3020 Plan (RE 3020) envisions producing 20% of electricity from renewables by 2030 while the 3rd Basic Energy Plan aims at a 30-35% by 2040.

Policy approaches to stimulate the energy transition have been diversified as well. Korea introduced the Renewable Portfolio Standard (RPS) scheme in 2012 and has kept raising the mandatory renewable share in an incremental manner (from 5% in 2018 to 10% in 2022). A Feed-in-Tariff (FIT)-based subsidy program is also in operation on a temporary basis to ensure a stable level of profits for small-scale power producers. Taking such policy actions have contributed to raising renewable capacity 1.6-fold and the share of renewables in the energy mix from 4.7% to 8.3% (including waste-to-energy) for the recent five years (2014-2018).

[Figure 2-5] Renewable energy in Korea



Industry sector

Since 1990, the Korean economy has quadrupled in scale due mainly to the growth in manufacturing sector which is also responsible for a significant portion of total GHG

emissions. In fact, the growth in manufacturing sector has been contributing to the constant increase in GHG emissions.

The two key policy tools for keeping the emissions from industry sector under control and helping to achieve its 2030 sectoral target are ETS and TMS. The ETS, in particular, helps businesses reduce GHG emissions in a cost-effective way by motivating them in the economic sense.

Enhancing energy efficiency is another strategic focus in cutting GHG emissions from the industry sector. The Energy Saving Company (ESCO) program launched in 1993 has supported total 4,358 cases of energy saving installations or upgrade worth 2.9 trillion won until 2017. The Government is also offering technical assistants to enterprises to adopt the Energy Management System (EnMS) which helps systematic management of corporate energy performances in terms of both demand and efficiency.

<Table 2-7> Government investment in ESCOs

	2010	2011	2012	2013	2014	2015	2016	2017
No. of cases	122	223	292	227	149	83	80	24
Financial support (KRW 100mn)	1,307	2,979	2,766	3,097	2,540	1,631	1,235	521
GHG reduction effect (thousand TOE)	95	211	233	175	166	157	96	32

Source 2019 Energy Report, Korea Energy Agency

Enterprises that consume large amount of energy (over 2,000 TOE per year) are required to undergo regular energy performance assessments to improve energy efficiency in their business operation by avoiding preventable energy loss. Since introduced in 2007, 6,406 business sites have gone through the energy assessments by which they could save 5,675 thousand TOE/year of energy and reduce 13,737,000 tCO_2eq of GHG emissions to date.

The Energy Efficiency Resource Standard (EERS) program requires energy producers to meet an energy saving target set up based on the volume of their energy sales. Pilot projects of EERS have been conducted in Korea since 2018. New projects are also under development to encourage end-use energy consumers to improve their energy efficiency.

Transportation sector

Forced by increasingly stringent regulatory standards to control vehicle emissions and accelerated by technology innovations from the Fourth Industrial Revolution (also known as Industry 4.0), the global automotive industry in the 21st century is rapidly becoming

green, smart, and service-oriented. As one of the world's major car manufacturing countries, Korea is striving to be agile in responding to future demand and cutting GHG emissions from the transportation sector.

Aiming at the world's most competitive future mobility industry by 2030, we are intensively investing in technology innovations in green vehicle production while coming up with various incentive programs to boost domestic demands for eco-friendly vehicles. The environment-friendly vehicle deployment target scheme requires automakers to produce and sell a certain percentage (15% in 2020) of eco-friendly vehicles of their new car sales. From 2020, the public sector can purchase eco-friendly vehicles only.

We are providing eco-friendly vehicle subsidies for different type of vehicles ranging from passenger cars, to buses, trucks, and two-wheelers. The Government is focusing on building necessary infrastructure to ensure EV drivers could easily find charging stations available nationwide.

Implementing such programs has contributed to a surge in accumulated number of eco-friendly vehicles which has quadrupled for the latest 3 years. We deployed the largest fleet of hydrogen vehicles in 2019 and was ranked 8th in the world in terms of the number of registered EVs (cumulative).

<Table 2-8> Electric and hydrogen vehicle deployment and their subsidies

Type of vehicle		2015	2016	2017	2018	2019
Eco-friendly vehicle registration (cumulative)	Electric	5,451	10,484	24,749	55,843	90,923
	Hydrogen	48	96	179	908	5,097
	Hybrid	178,102	238,303	322,058	416,597	520,799
Subsidies (KRW 100 mn)	Electric	707	1,882	2,432	3,905	6,330
	Hydrogen	19.8	79.5	185.8	298.4	2,265

In 2007, Korea introduced a requirement of renewable fuel (biodiesel) content in transportation fuel (diesel) at a certain rate. Produced mainly from waste cooking oil, biodiesel is a green alternative fuel that contributes to preventing environmental pollution as well as reducing GHG emissions. The mandatory biodiesel content has been raised from 0.5% in 2007 to current 3%.

On the freight system, we are promoting a modal shift from road to lower emissions alternatives such as railway and marine transport. Various measures to cut emissions from freight transportation are in place targeting rail, shipping, and aviation industry, for example, by introducing LNG-fueled ships and expanding shore-side electricity in the marine transport.

Building sector

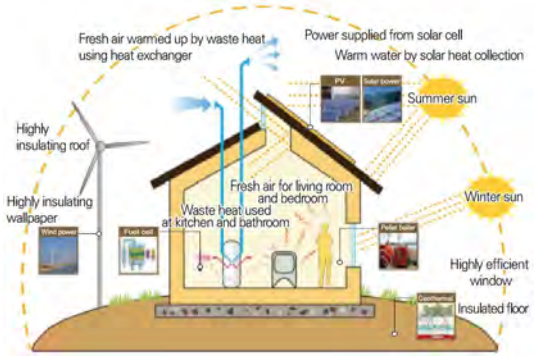
The amount and patterns of GHG emissions from the building sector are largely affected by countries' residential conditions and people's lifestyle. Current mitigation polices in the building sector in Korea focus on saving energy consumption in apartment buildings, the most common housing type in Korea, and enhancing energy efficiency in lighting and home appliances.

The zero-energy building project is currently underway to promote the construction of green buildings that are powered and heated by renewable energy sources and have the maximum insulation performance that lowers the energy demand. Any public buildings newly constructed with the gross floor area (GFA) at 1,000㎡ or larger should be designed as a zero-energy building from 2020, and all public and private buildings with their GFA larger than 500㎡ will be required to be zero energy by 2030.

[Figure 2-6] Zero energy building

- Powered and heated by renewable energy sources and have the maximum insulation performance that lowers the energy demand

Passive		Active		
Minimize energy use for heating/cooling (High insulation performance)	+	**Generate energy from renewables** (Solar power, geothermal heat)	⇨	**Zero Energy Building**



- Energy efficiency grade 1^{++} or higher and equipped with a Building Energy Management System (BEMS). Classified into five grades based on energy independency.

Energy efficiency grade	Energy Independency *	Zero Energy Grade
Grade 1^{+++*} or higher (* Saving 80% of energy compared to Grade 7) ※ Korea's energy efficiency grade: Highest: Grade 1^{+++} – Lowest Grade 7	100% or higher	1
	80 ~ 100%	2
	60 ~ 80%	3
	40 ~ 60%	4
	20 ~ 40%	5

Besides, the green remodeling program offers financial supports for building renovation projects to improve energy efficiency. Energy efficiency standards for consumer products and home appliances will also be strengthened progressively, for example, a phase-out of fluorescent lights by 2027.

Chapter 3

Korea's 2050 Vision

1. Korea's 2050 Vision

The Republic of Korea moves towards the goal of carbon neutrality by 2050.

The Korean New Deal will serve as a stepping stone to reach carbon neutrality by 2050. Korea will harness green innovations and advanced digital technologies to create synergies between the Green New Deal and the Digital New Deal, the two pillars of the Korean New Deal. Korea will also take decisive action especially in supporting and investing in the development of innovative climate technologies to achieve carbon neutrality by 2050.

Tackling climate change requires global efforts and collective engagement. Korea will lead by example to help the international community jointly make efforts to reach carbon neutrality by 2050.

2. Principles

Contributing to global climate action

As a party to the Paris Agreement and a responsible member of the international community, Korea will faithfully join and contribute to the global efforts to hold the increase in the global average temperature to well below 2°C above pre-industrial levels and pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels.

Efforts to reduce GHG emissions will provide an opportunity for sustainable development. We are keen to pursue joint efforts with other countries in taking robust climate action and supporting developing countries by sharing our innovative technologies and know-hows.

Laying the foundation for sustainable and carbon-neutral society

Korea will strive to build capacity to lead the ongoing paradigm shift in the global energy system. Our ultimate goal is to overcome resource scarcity and energy dependence and build a sustainable and carbon-neutral economy.

The first step towards the goal is to phase out the use of fossil fuel, which requires a major overhaul of the current power mix. To put in place a green, zero-emissions power supply system, we will significantly reduce coal power generation while increasing energy efficiency in industry, buildings and transportation sector up to the level of the world's leading countries.

To create a sustainable environment for industrial development, we will foster future growth engines by harnessing technological innovations and decarbonizing our industry structure. The Government is closely collaborating with businesses and industries to promote digital transformation in all sectors, which will lay the groundwork for optimal use of energy and application of future technologies including hydrogen production/supply/use and Carbon Capture, Utilization and Storage (CCUS).

To ensure a just transition towards carbon-neutral society, especially for those working in industries depending on fossil fuels, the Government will create new job opportunities in new, alternative industries and provide re-training support for them. The Government will also provide support to build low-carbon infrastructure in fossil fuel-dependent communities that are likely to face job losses in the process of energy transition.

Moving away from the fossil-fuel based production, distribution and consumption patterns, we will create a circular cycle of resources that will ultimately enable people to achieve universal goals for environment and health. Meanwhile, nature-based carbon sinks, i.e. forests, wetlands and marine ecosystems, are to be continuously expanded to accelerate the transition to a carbon-neutral society.

Action at all levels

Given Korea's current economic structure and industrial portfolio, moving away from the fossil fuel-based economy requires a sweeping change in its entire system. Balancing between emissions reduction and industrial growth means that all sectors including the basic patterns of people's daily lives should be reshaped.

This transformative change could take place only when a broad consensus is reached among various stakeholders of our society from industry, civil society and academia. In particular, public support and engagement are essential. It is absolutely imperative that the public recognizes decarbonization as the only way forward. Greater public recognition will build up a momentum for accelerating the action for carbon-neutral transition.

The Government will inform the people of the detailed costs to be incurred from this transition as well as the benefits of climate action in an open, transparent manner. Parting

from the fossil fuel economy, which has been the basis of Korea's growth for the past decades, is certainly a challenging and arduous process. The Government is ready to lead this process by sharing information with the people on gains and losses of this transition and seek their consent. The costs should be borne in a fair and equitable manner by all members of society depending on their roles and responsibilities.

Policymaking for climate change response should be a participatory, democratic and inclusive decision-making process that engages all and leaves no one behind.

3. Key elements of the 2050 Vision

Key element 1: Expanding the use of clean power and hydrogen across all sectors

In achieving the 2050 Vision, the most important key element is accelerated energy transition towards carbon neutrality. Solar, wind, hydro, and other types of renewable energy should be the central sources of energy supply. CCUS technologies should be employed in the use of coal and other fossil fuel-powered energy and LNG power generation to significantly cut down on GHG emissions in the long-term.

Evidently, it is important to reorient the existing energy supply system. Technological innovation could help bring about this fundamental change by making renewable energy more affordable. Continued efforts are needed to bolster market-based policies such as carbon pricing and to advance the power system at the national level. The intermittency issue remains a challenge for some renewable energy sources, which should be addressed considering Korea's geographical difficulty of supplying electricity from overseas. As the percentage of renewable energy in the power mix gradually increases, it is essential to keep the electricity output predictable and reliable throughout the entire power grid.

A system-wide integration of EVs, ESS and hydrogen technologies is another viable option, which could be achieved by utilizing advanced ICT and Industry 4.0 technologies. With this, consumers will be able to communicate with each other and trade the electricity they produced from distributed power sources on a smart grid. This will change the traditional concept of consumers into "prosumers," who both produce and consume energy.

Most sectors of our society – transportations, cooling and heating systems and industrial processes – that are using fossil fuels need to use clean electricity in the future.

To achieve Korea's 2050 Vision, most of the current means of transportation running on fossil fuels should be replaced with alternative modes of transport powered by electricity, hydrogen and other clean energy sources.

These gradual changes will form a dominant trend by 2050 especially in road transportation. By 2050, electric and hydrogen-powered vehicles are expected to become widely popular, and other modes of transportation including air, sea and rail could also experience a similar transition.

Key element 2: Improving energy efficiency to a significant level

"Energy efficiency" is by far the most eco-friendly and economical energy resource[30]. Improving energy efficiency saves costs for businesses, making them more competitive in the market. With this enhanced competitiveness, companies could produce highly-efficient products, which ultimately contributes to the overall industrial growth. It is a highly economical strategy that could also help reduce energy consumption. In the absence of natural resources[31], improving energy efficiency is one of the most essential strategies for Korea, especially in relation to its energy security.

Once energy efficiency is improved, it will ultimately lead to a decreased energy supply. Compared with the huge upfront cost of developing ESS and hydrogen technologies, improving energy efficiency is the most cost-effective option that should be considered as a policy instrument.

There are a number of time-tested solutions that are effective in improving energy efficiency: enhancing vehicle fuel efficiency, strengthening building insulation, using highly-efficient appliances and deploying a smart energy management system. These solutions are already in use or readily available for all sectors from the government to industry to the public.

The Government's clear policy vision for improved energy efficiency along with balanced regulations and incentives will encourage active engagement and efforts from all sectors and ultimately help achieve a significantly improved energy efficiency.

30) The International Energy Agency estimated that improvements in energy efficiency to be the most effective policy tool for mitigation in 2017.

31) As of 2017 the amount of imported energy was USD 109.5 billion, accounting for 22.9% of Korea's total import amount.

Key element 3: Commercial deployment of carbon removal and other future technologies

Korea's manufacturing sector is largely dominated by energy-intensive industries such as steelmaking, cement and petrochemical production. Such an industrial structure makes it all the more urgent for Korea to further develop and commercially deploy future technologies, i.e., hydrogen technologies, CCUS, etc., to trigger the transition from low-carbon society into a carbon-neutral one.

The application of such technologies is especially important because Korea's major industries produce a high level of CO_2 emissions during their manufacturing process: manufacturing of cokes (reducing agent for steelmaking); calcination of limestone (major feedstock of cement production); and thermal cracking of naphtha (used in petrochemicals production).

Key element 4: Scaling up the circular economy to improve industrial sustainability

In a linear economy, raw materials are extracted to make products and after consuming the products, they are thrown away. In a circular economy, however, materials are reused and products are recycled over and over in a circular cycle that promotes sustainability. Transition to a circular economy is a strategy that will help us reduce GHG emissions while conserving our ecosystems. Lifecyle approach is the key to ensuring product recyclability throughout production, consumption, recycling, and disposal, which minimizes the resource and energy inputs. Reliance on new future technologies could increase uncertainties in achieving emissions reduction targets, but a stronger circular economy could reduce such reliance, having an effect of lowering the uncertainties.

Key element 5: Enhancing carbon sinks

Land, forests, and marine ecosystems are the fundamental elements of the environment and they provide a variety of goods, foods and ecosystem services essential for human survival. They also function as strong carbon sinks that absorb and store CO_2, playing an important role in the transition towards a carbon-neutral society. Expanding and managing the forests with high carbon storage capacity, practicing sustainable forest management and promoting the use of wood products greatly contribute to reducing GHG emissions.

<Table 3-1> Mitigation options and outlook by sector(non-exhaustive)

Mitigation options		Outlook		
		Mitigation effect	Technological maturity	Cost
Energy Supply (Electricity & Heat)				
1. Use CCUS		●	◐	○
2. Improve energy mix		●	●	●
3. Promote hydrogen-based economy	Introduce fuel cell	●	◐	◐
	Supply hydrogen	●	◐	○
Industry				
1. Use hydrogen technology and recycle and reuse materials		●	◐	○
2. Convert into new materials and promote products with high added values		●	○	○
3. Improve equipment efficiency		●	●	●
4. Promote smart factory and smart industrial complex		◐	●	◐
5. Use CCUS		●	◐	○
6. Use low-carbon fuels and materials		○	●	●
7. Reduce emissions from industrial process		●	●	●
Buildings				
1. Improve building energy efficiency		●	●	○
2. Supply highly efficient equipment		◐	●	◐
3. Promote smart energy management		○	◐	◐
4. Promote renewables and use waste heat		●	◐	○
Transportation				
1. Mix biofuels for road transportation		◐	●	◐
2. Promote eco-friendly vehicles and improve average fuel efficiency		●	●	◐
3. Advance railway system		○	◐	○
4. Advance aviation system		○	◐	○
5. Advance shipping system		○	◐	○
6. Promote traffic demand management		◐	-	-
Waste				
1. Recycle and reduce at source		●	●	○
2. Methane gas recovery	Hygienic landfills	◐	●	◐
	Biological treatment facility	●	●	◐
3. Increase aerobic operation of landfills		●	○	◐
4. Replace with bioplastics		●	○	●
Farming				
1. Transition to smart farming		◐	●	◐
2. Develop and deploy low-carbon agricultural practices		●	◐	◐
3. Promote participatory policies for farmers and consumers		◐	◐	◐
4. Scale up deployment of eco-friendly energy		●	●	◐
Carbon sinks (forest)				
1. Expand forests(afforestation, reforestation)		◐	◐	◐
2. Maintain carbon sinks (forest management)		●	◐	●
3. Expand timber supply		◐	◐	◐

* Outlook indictor ●: high, ◐: medium, ○: low

Source 2050 Low-carbon Vision Forum's proposal (February, 2020)

Chapter 4

Visions and Strategies by Sector

1. Energy supply

1.1 Status

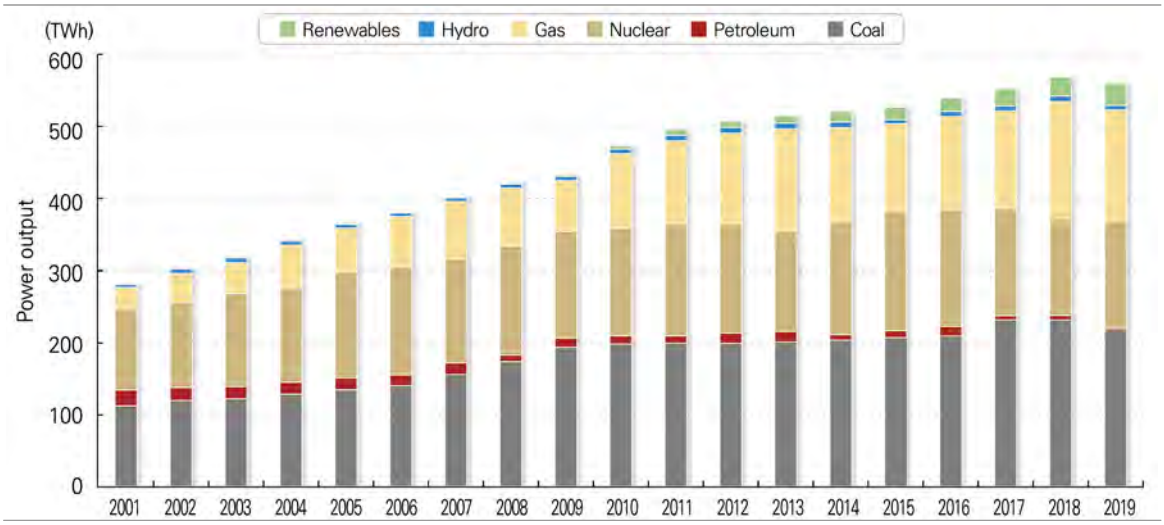
Power mix

As of 2017, Korea imported 94% of its energy supply from overseas and was ranked as 9th largest energy consumer in the world. Our rapid economic growth in the past half a century was possible thanks to the Government's policy drive to foster the manufacturing sector. Reliable power supply was essential as our focus was on investing in manufacturing and increasing export.

Korea's electricity policy has been largely focused on increasing the supply volume by using coal and nuclear power as two main sources of baseload power due to their relative reliability and affordability. Of the total generated electricity in 2017, 43.1% was from coal while 26.8% was produced by nuclear power. When combined, the two power sources produced 70% of the total power supply. In the early 2000s, nuclear power took up 40% of the total power mix, but the percentage has been in decline since then, as coal and LNG have been continuously taking up an increasing share.

The share of electricity in end-use energy is also increasing sharply. In 1990, the percentage of electricity was only 10.9% of the total end-use energy, but climbed up to 19.2% in 2010. As more sectors and energy uses are experiencing electrification, this upward trend is likely to continue.

[Figure 4-1] Power mix trend



Source Korea Electric Power Corporation statistics (2019)

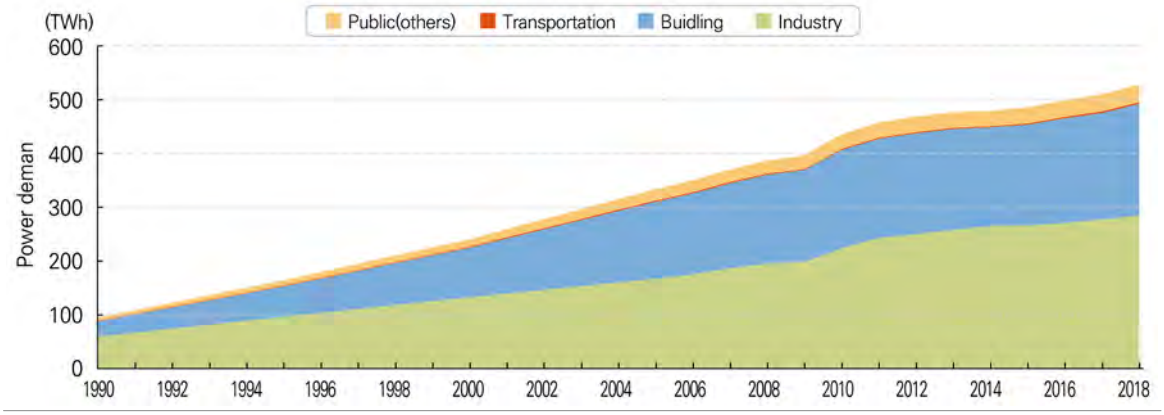
Power demand by purpose of use

Power consumption had been on the steady rise until its peak at 526 TWh in 2018. However, considering that the annual average growth rate of power consumption for the recent five years (2014-2018) has been halved from that of the previous five years (2009-2013), the power consumption growth is on a slowing trend.

Power demand by sector in figure 4-2 shows that industrial use accounts for more than 50%, but the percentage has been declining after reaching its peak of 55.4% in 2014.

On the contrast, electricity consumed by both commercial buildings and homes is on the rise and the power demand in the transportation sector is also expected to grow as an increasing number of EVs will be deployed.

[Figure 4-2] Power demand by sector

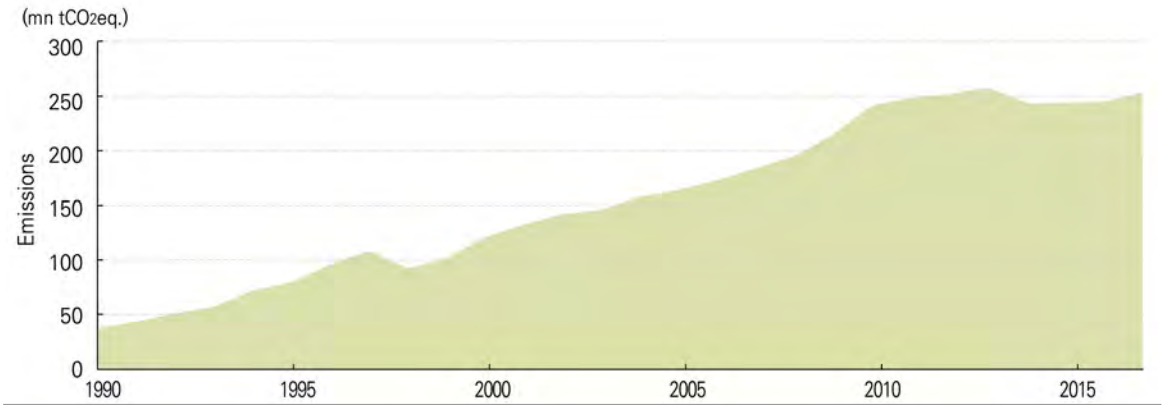


Source Korean Statistical Information Service (2019)

Power sector emissions

Emissions from the power sector are steadily increasing due to rising power demand and deteriorating sectoral emissions intensity, but since 2010, the emissions growth in the sector has been slowing down. In 2017, the emissions from the power sector increased by 6-fold from 1990 level, accounting for 36% of Korea's total emissions.

[Figure 4-3] Trend of emissions by power source



1.2 Energy sector's vision

Producing zero-emissions electricity in an eco-friendly way and using clean power in greater scope are the keys to achieving the Korea's 2050 Vision. To this end, low-carbon energy should serve as the primary power source in energy portfolio and advanced technologies such as CCUS should be fully harnessed to ultimately achieve carbon neutrality of the power sector.

Reducing GHG emissions in the power sector can be achieved by two different approaches: i) by improving emissions intensity in power production; ii) by managing power demand. This section mainly focuses on the power sector's strategies to improve emissions intensity while strategies and tasks of managing power demand will be detailed in later sections of this chapter.

The power sector plays a key role in achieving Korea's NDC and its 2030 emissions reduction target as well as the 2050 carbon neutrality. To this end, deployment of innovative renewable energy and fossil fuels with CCUS are the two essential elements that should be secured.

The existing power system should be changed into a renewable-based system, i.e. wind and solar. Fossil fuel-based power generation will no longer be a main contributor to baseload power, but remain as a supplementing power source for intermittent renewable energy. Applying CCUS to fossil fuel-based power plants must be considered to this end.

For carbon neutrality in non-power sector, the production of clean electricity and hydrogen should be increased, and accordingly, power demand is expected to rise as well. Considering this rising power demand, a more reliable power supply system needs to be developed in conjunction with effective demand management.

Renewable energy-oriented power supply

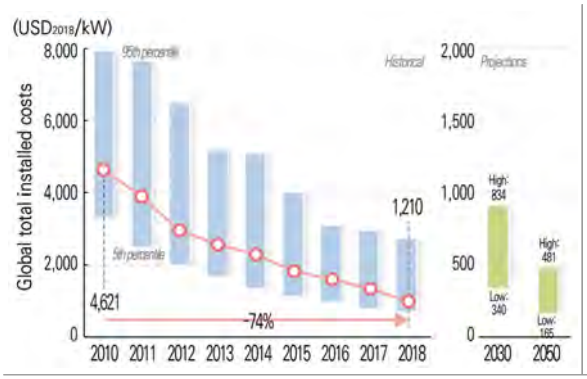
For the 2050 carbon neutrality in the power sector, renewables, i.e., wind and solar and other clean renewable energy sources should become dominating power sources by 2050. In 2010, renewable energy accounted for only 1.2% of the annual power output, but it has soared up by 3.5-fold to 4.2% in 2018 (not including waste-to-energy). This rapid growth was possible due to the Government's variety of policy supports including setting renewable energy production target at 20% by 2030, introduction of the Renewable Portfolio Standard (RPS) and Korean-type Feed-in Tariffs (FIT) systems.

In the 3rd Basic Energy Plan formulated in May 2019, the Moon Jae-in administration has announced an ambitious goal of producing 35% of electricity from renewable energy sources by 2040. By 2050, this trend of energy transition is expected to accelerate, making renewables the most critical power source in Korea. Continued technology development will lower the production cost of renewable energy. This, along with enhanced power system flexibility, will help build up momentum for the energy transition.

In fact, investment cost for solar power dropped from KRW 3,745,000/kW in 2011 to KRW 1,648,000/kW in 2017. For wind power, the investment cost decreased from KRW 2,576,000/kW in 2012 to KRW 2,102,000/kW in 2017. This trend of decreasing investment costs for renewable energy is likely to continue in the years to come. A study by the Korea Energy Economics Institute suggests that the production costs of solar and wind power, currently higher than those of fossil fuel power, will become comparable to those of coal, LNG and other fossil fuels by 2030[32]. After 2030, renewable energy will become an economically viable option due to its cost-competitiveness with its increased deployment.

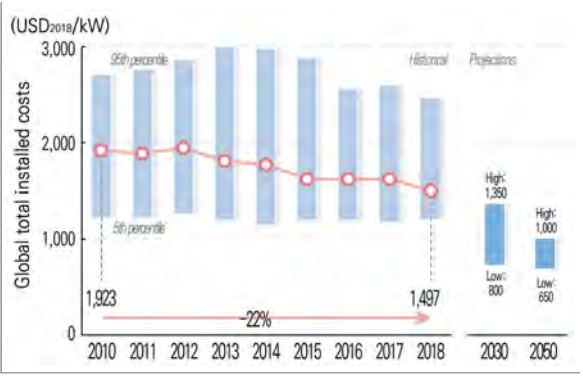
[Figure 4-4] Projected investment cost for renewables

Solar PV(utility)



Source IRENA, Future of Solar Photovoltaic (Nov. 2019)

Onshore wind



Source IRENA, Future of Wind (Oct. 2019)

Fuel cell and green hydrogen

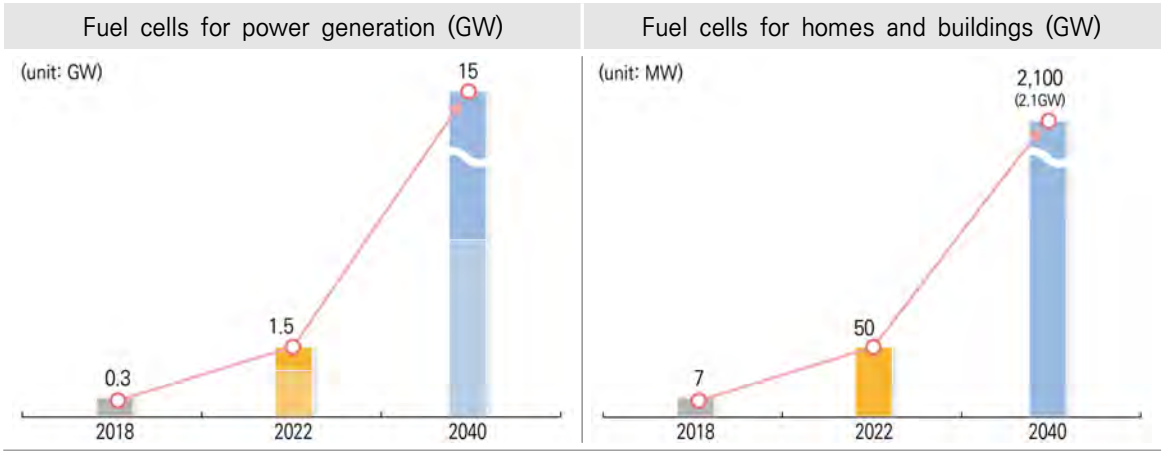
Korea considers hydrogen as an important future power source in accelerating industrial innovation and reducing GHG emissions. To fully harness this critical power source, we have announced in 2019 the Roadmap to Promote Hydrogen-based Economy, setting a path to move forward as a leader in this area.

The purpose of the roadmap is to build a foundation for producing green hydrogen by utilizing renewable energy sources, and using the produced hydrogen in fuel cells as well as in mobility of various forms. The roadmap aims to drive a paradigm shift from the existing

32) Korea Energy Economics Institute, Study on the estimation of levelized cost of energy by source, Feb. 2018

carbon-based system into a hydrogen-oriented, eco-friendly energy system. The Government has developed a plan to build up a fuel cell facility to generate 8GW of electricity by 2040 and will continue to scale up the production of fuel cells. A variety of policies are to be put in place to expand the supply of green hydrogen as well.

[Figure 4-5] Deployment plan for fuel cells using hydrogen



Source Roadmap to promote hydrogen-based economy (2019)

Fossil fuels with CCUS

To continue to use fossil fuel as a power source, the use of CCUS technology is critical. Coal and LNG power plants could continue to play an important role in solving renewable energy's volatility issue and enhancing energy security if their CO_2 emissions are captured before they are released into the air. We will continue to move ahead with strong policies to phase out coal power generation, which is one of the Moon Jae-in administration's national priorities, and as a result, a significant reduction of GHG emissions from coal-fired power plants is expected by 2050.

Natural gas power generation will continue to play a bridging role while the current energy system re-aligns around renewable energy. LNG will remain as an important power source in Korea's effort to enhance its readiness for unusually high peak demands and diversify power sources to strengthen its national energy security.

CCUS is an essential option to reduce CO_2 emissions and achieve our NDC and 2030 emissions reduction target. Government-funded R&Ds are underway to build an infrastructure for developing and demonstrating technologies that can reduce nearly 10 million tCO_2eq by 2030. For a wider use of CCUS technology, further technology development is needed to achieve carbon neutrality of the power sector. However, expansion of CCUS technology requires: i) technological advancement and subsequent cost reduction; ii) large-capacity storage facilities and their social acceptance; and iii) market-based incentives balanced with regulatory approaches.

Assuming the level of CCUS technology is fully matured to an advanced level and its wider application is realized, the technology is expected to be applied to CO_2 emissions from coal as well as natural gas power generation.

1.3 Energy supply sector strategies

Addressing technological limits in renewables

Solar and wind energy is supplied from natural energy sources that are endlessly available. Once a renewable energy facility is constructed, in addition to the benefit of zero-emissions, almost no marginal cost is incurred. In other words, renewables are eco-friendly solutions that provide humans with clean and endless energy source.

However, for renewables to completely replace conventional power sources – coal, nuclear and natural gas – that have been proved to be reliable, and to become a main power source, two limitations of volatility and intermittency should be addressed in advance. Advanced ICT networks, Industry 4.0, innovative ESS, and hydrogen as a fuel will significantly contribute to addressing such limitations and making energy transition possible. To solve the volatility and intermittency problems, it is critical to: i) enhance predictability of the power output; and ii) build up a reliable and flexible power backup system.

First, to enhance predictability of the power output from renewables, an accurate prediction should be made possible with comprehensive assessment of various factors – Korea' climate conditions, types of renewable energy, and facility locations and scales. Second, a flexible real-time operation system should be introduced in the power market. Current power market system in Korea determines daily power output a day before the power is produced, and does not allow for a flexible operation. To ensure a flexible and reliable power grid operation, advanced control technologies and ESS should be adopted.

In Korea, a series of effective solutions including integrated control system and real-time power market system are currently being developed[33] to address the volatility issue of renewable energy. It is also important to diversify energy sources and utilize ESS for stable management of intermittency and peak demand issues of renewables. Fuel cells using green hydrogen, ESS and pumped-storage hydropower will provide optimal technological and environmental solutions to store the surplus power generated from renewables while addressing intermittency issue. Fossil fuel-based power plants with CCUS could also serve as a crucial power backup facility for intermittent renewable energy sources.

33) The 8th Basic Plan for Power Supply and Demand (Dec. 2017), the 3rd Basic Energy Plan (May 2019)

Building enabling environment for renewables

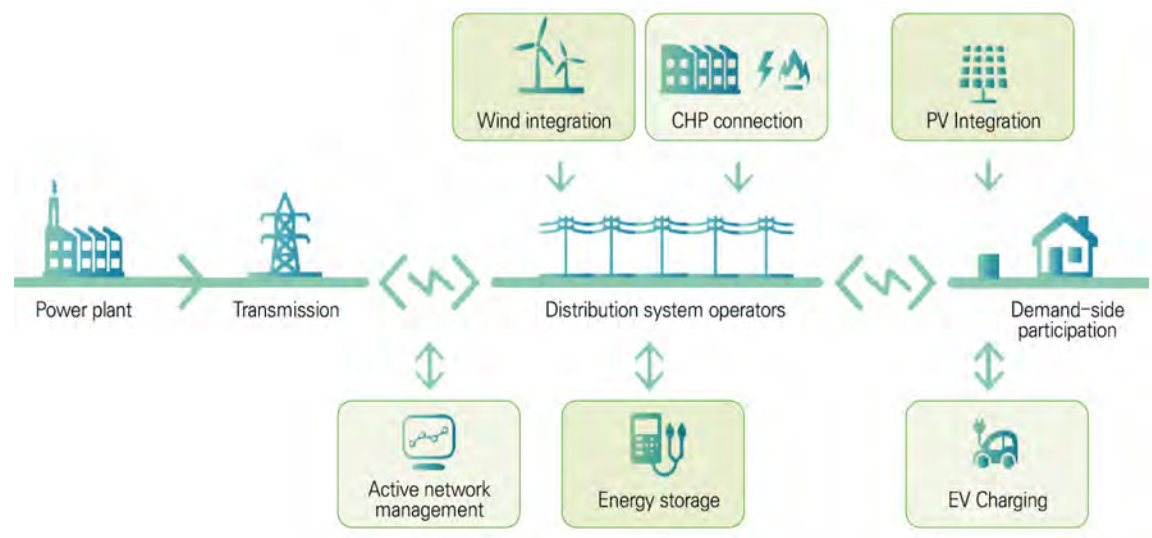
Conventional fossil fuel-based power grid was operated in a centralized, one-way energy supply system. This system was focused on facilitating the operations of large-scale power generation using coal and nuclear, which in the end resulted in many large power plants densely located in specific areas. This has caused a geographical mismatch between power supply and demand and subsequently, long-distance transmission grids have caused various social conflicts.

Renewable energy-oriented power system will allow for an opportunity to solve such problems of the existing centralized power system. There is no limited scope in generating power from renewable energy because anyone can participate in production at any scale. Our strategy is to move away from centralized, one-way system, and change into a decentralized, participatory and multi-way grid system.

For instance, anyone could install solar panels on top of buildings, lands, and transportations. Wind power already has various business models where local towns, cooperatives and residents could participate in power production and share profits. New business models using Distributed Energy Resources (DER) are expected to contribute to the proliferation of renewable energy as well. Volt-to-grid system using EV batteries, peer-to-peer trading of excess renewable energy, and ESS could all be connected to a virtual power plant, which acts as an intermediary between these small-scale DER and electricity markets.

This transformation indicates energy consumers and producers are not separate concepts anymore. Prosumers who not only consume but also produce energy will soon become a universal concept. The Government will move in step with this trend and focus on developing the systems for various DER.

[Figure 4-6] Vision for new energy supply system

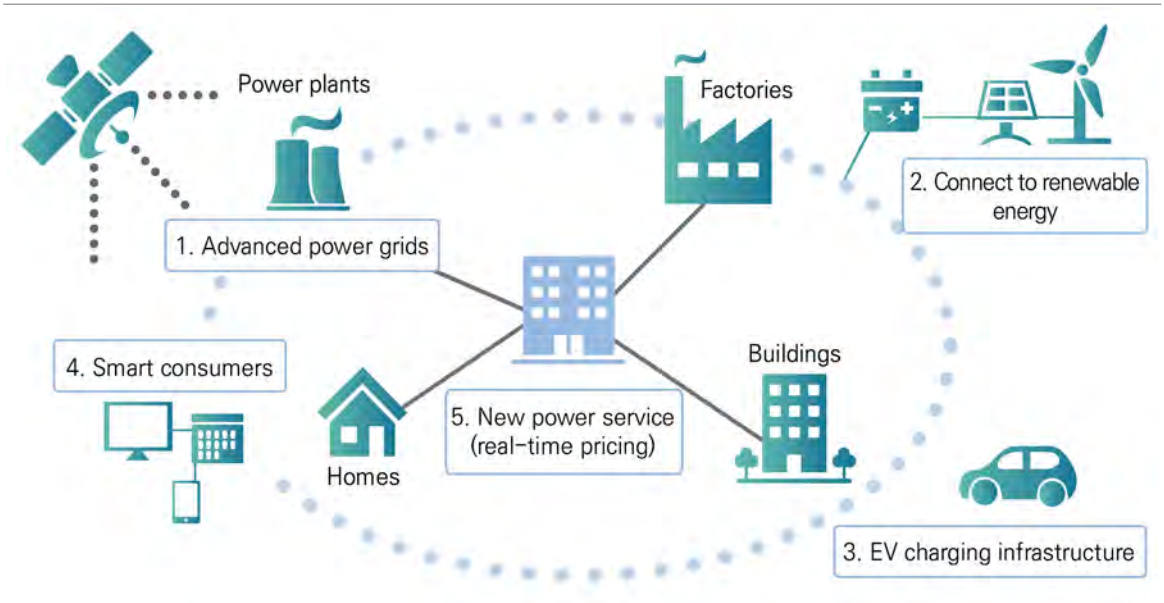


The Government is well-positioned to lead such transformation in time in the era of energy transition and create an enabling environment for renewable energy. Already, proliferation of distributed, participatory power sources is one of the Korea's top policy visions. The Government has set the goal of increasing the power generated from DER up to 30% by 2040. Policies to improve existing electricity markets and grid systems are now in development to facilitate market trading of various DER and their connections to grids.

Deployment of smart grids is also another important task to be undertaken in order to secure demand flexibility. Power supply efficiency can be maximized if supply is matched with demand. Smart metering that implements time-of-use or season-of-use pricing, or Demand Response (DR) are the prime examples of mechanisms designed to match demand with supply.

These policies seek to adjust power demand by providing consumers with economic incentives to control their consumption. This not only reduces peak loads but also allows power producers to secure reliability and affordability in supplying power. This win-win policy models ultimately aim to build up a smart grid system which is under development as part of demonstration projects in many cities of Korea including Jeju Island, followed by Seoul and Gwangju.

[Figure 4-7] Smart grid



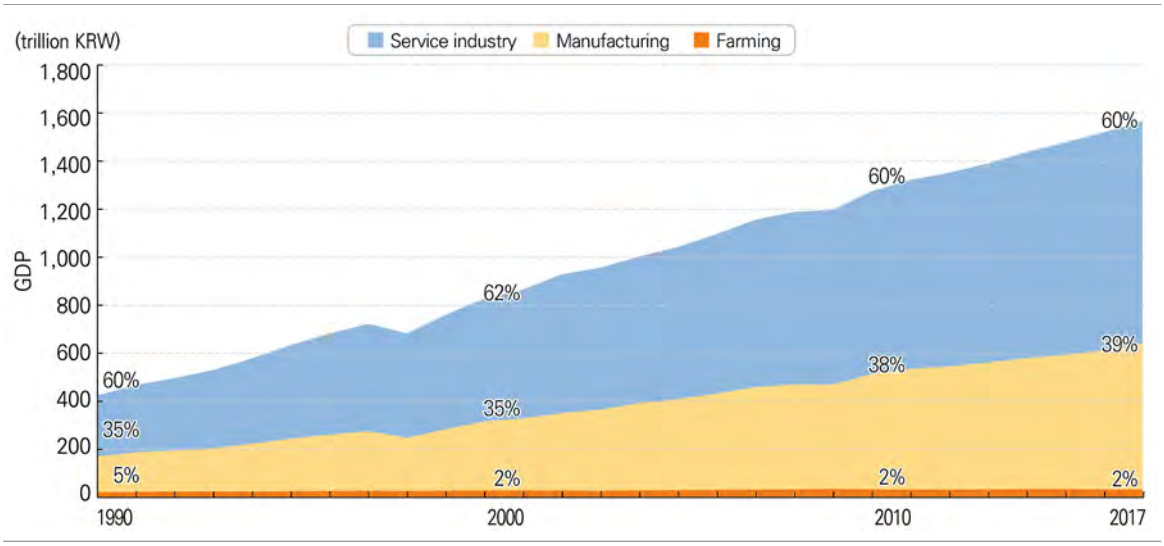
2. Industry

2.1 Status

Korean's economic structure

In 2017 Korea's GDP recorded a high annual average growth rate of 5% compared to 1990 level (OECD annual average growth rate was 4.4%). This high growth rate is attributable to the growth in industry sector, which accounts for 90% of the total GDP. Manufacturing sector[34] accounted for 39% of Korea's GDP as of 2017, representing a smaller share than the service sector which took up 60%. However, industry sector's growth rate of added value[35] was estimated to be higher than that of the service sector. This is due to Korea's focus on manufacturing – steelmaking, shipbuilding, automotive, petrochemicals and semiconductors production – as the national industrial base with its export-oriented growth strategy.

[Figure 4-8] Change in Korea's economic structure



Manufacturing creates 80% of the total added values from the industry sector. Of the manufacturing sector, the percentage of added values created by metal fabrication[36]

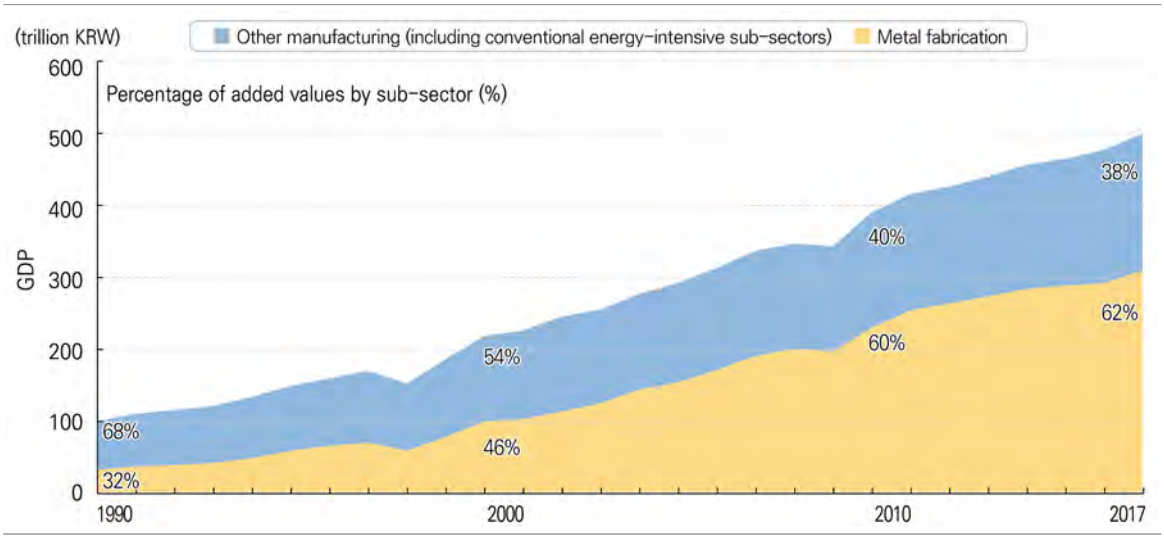
34) Industry sector is comprised of sub-sectors of mining, manufacturing, construction and Social Overhead Capital.

35) Growth rate of added value (annual growth rate between 1990 and 2017): industry sector 5.4% / service sub-sector 4.9%

36) Semiconductor, display, electrics, electronics, machinery, automobiles and shipbuilding

increased from 32% in 1990 to 62% in 2017 while steelmaking, petrochemicals production and other energy-intensive sub-sectors saw their rates decrease from 68% to 38% during the same period. This was due to the restructuring in the manufacturing sector that has taken place during this period. The Government policy from the 1960s to the 1980s focused mainly on input-driven growth strategy and large-scale process industry, i.e. steelmaking, petrochemical and cement manufacturing. However, with technological advancement and growth of machinery industry in the 1990s, semiconductors, electronics, automotive, shipbuilding and other technology-intensive sub-sectors started to emerge as flagship industries. Since the 2000s, knowledge-based economy and ICT have become main drivers for growth and as a result, semiconductors, display panels and IT industries are playing a key role for Korea's economic growth.

[Figure 4-9] Change in added values in manufacturing sub-sectors

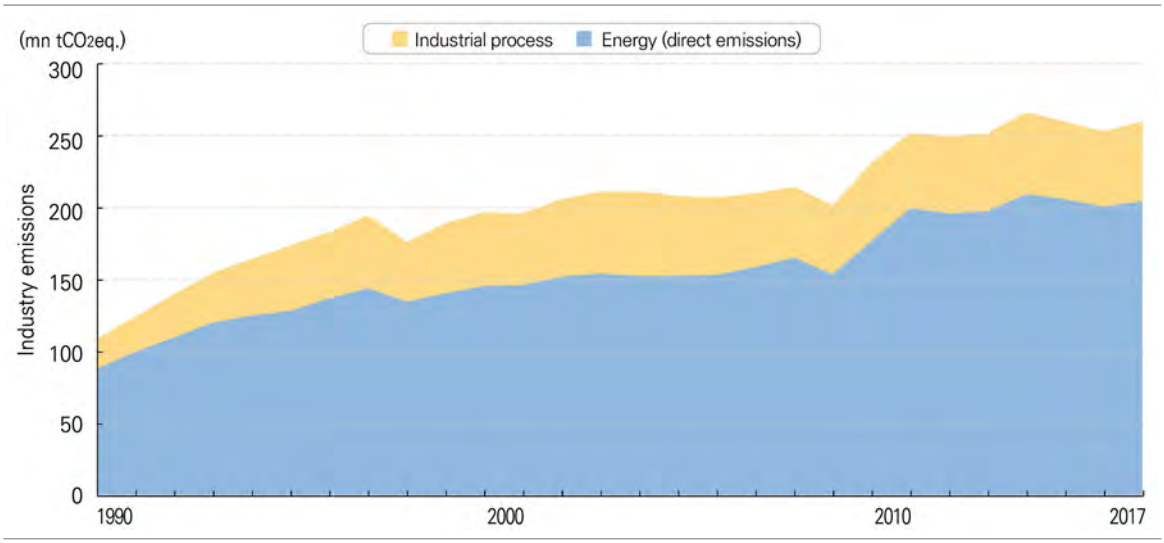


Industry sector emissions

As of 2017, industry sector contributed 37% of Korea's total GHG emissions (54% if indirect emissions were included), the rate on a par with the power sector's emissions, both of which are the highest rates of all the sectors listed under this chapter. There are two main sources of emissions from industry sector: i) emissions from fuel combustion, i.e. coal, petroleum, and gas, and ii) emissions from industrial processes. The emissions from fuel combustion take up a majority share of the total emissions.

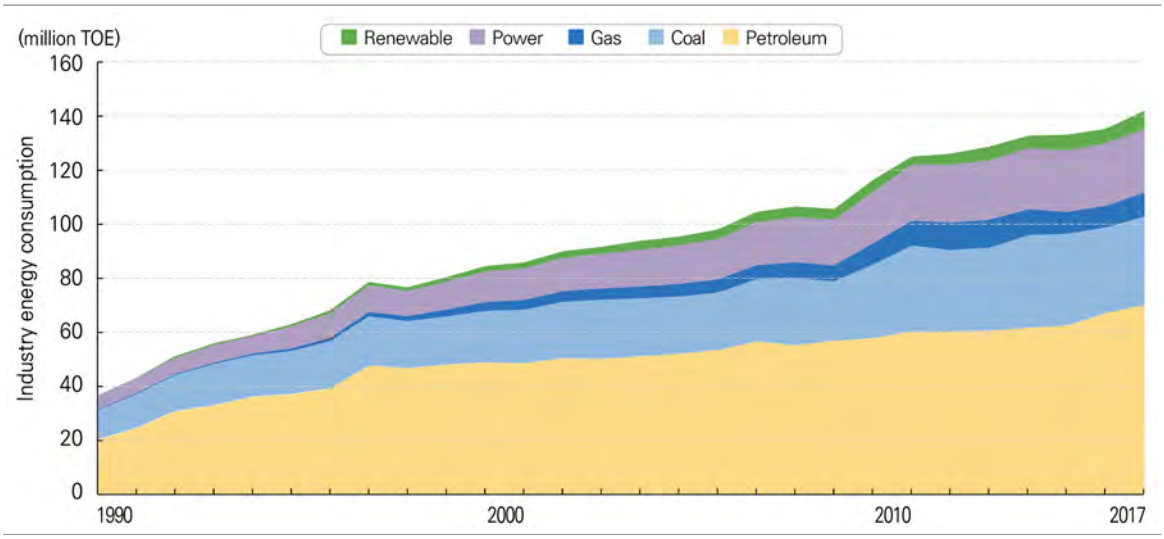
As of 2017, emissions from energy use accounted for 86% while emissions from industrial processes recorded 14%. The trend for the past decade indicates that average annual direct emissions from energy use (not including indirect emissions from electricity use) have increased by 2.0% while average annual emissions from industrial processes have risen only 0.5%.

[Figure 4-10] Industry sector emissions



The figure 4-11 shows us the energy consumption by source in the industry sector. It indicates that 70% of energy use in industry sector consists of petroleum and coal, which suggests naphtha and cokes used in energy-intensive sub-sectors such as petrochemicals production and steelmaking have caused high emissions. Therefore, low-carbon transition in such energy-intensive sub-sectors is most urgently needed.

[Figure 4-11] Industry energy consumption by source

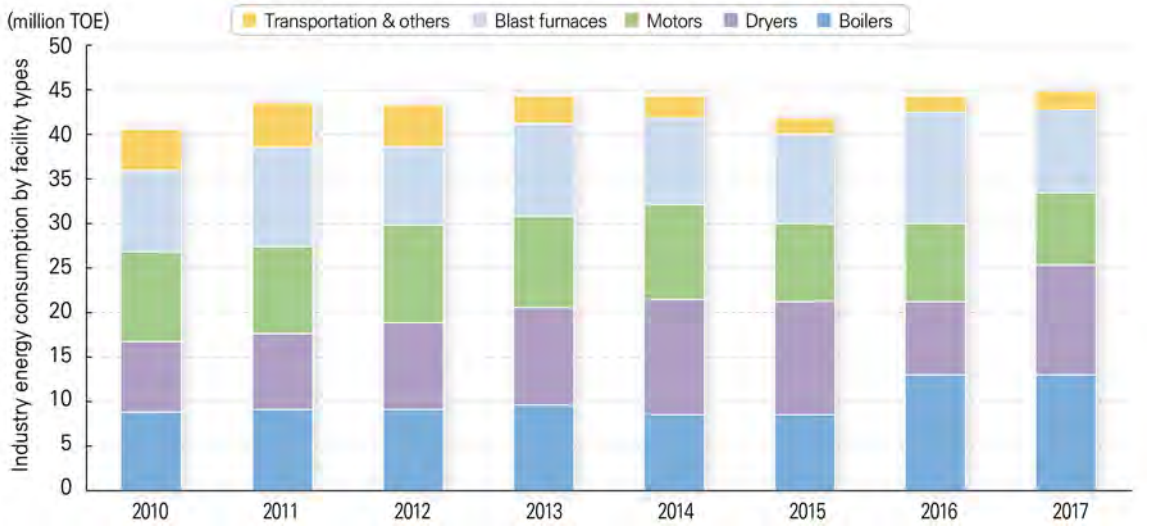


The figure 4-12 displays how much energy has been consumed by different types of industry facilities[37]. The estimates suggest energy consumed by boilers has increased from 22% in 2010 to 29% in 2017 while energy consumption from furnaces has declined from 20% to

37) The value does not include the amount of naphtha and cokes used in industrial processes.

27% during the same period. This is mainly due to the increase in the number of facilities that needed direct heating.

[Figure 4-12] Industry energy consumption by facility types[38)]



2.2 Industry sector's 2050 vision

Considering ever-growing public demand for a cleaner environment and tightening international control over GHG emissions, a low-carbon transition is essential in energy-intensive industries using conventional fuels.

GHG emissions reduction will provide more opportunities for growth for the industry sector and enhance the sector's sustainability. Those opportunities will include improved energy efficiency and enhanced international competitiveness.

Industry sector has many options to reduce its GHG emissions: improving energy efficiency, conversion into low-carbon fuels, applying CCUS technology and introducing innovative industrial processes. However, there is no silver bullet in dramatically reducing emissions across industries. Each industry has its own way of using energy and its emissions types and technology levels vary. One-size-fits-all option could create gaps across different industries and thus, a variety of mitigation options should be considered in achieving the industry sector's 2050 vision.

38) The value does not include the amount of cokes used in steelmaking and the amount of naphtha used in oil refinery and petrochemical industry. (Energy consumption survey, Ministry of Trade, Industry and Energy)

The industry sector's 2050 vision presented in this section takes into account characteristics of industry sub-sectors, and factors in various mitigation options in consideration of their applicability. Of all technology options, the ones that are already in industrial use are included as the industry sector's mitigation options. Other technologies that have not been developed for commercial use yet, but has high potential for application in the near future, are also included as mitigation options.

Applying new, future technologies

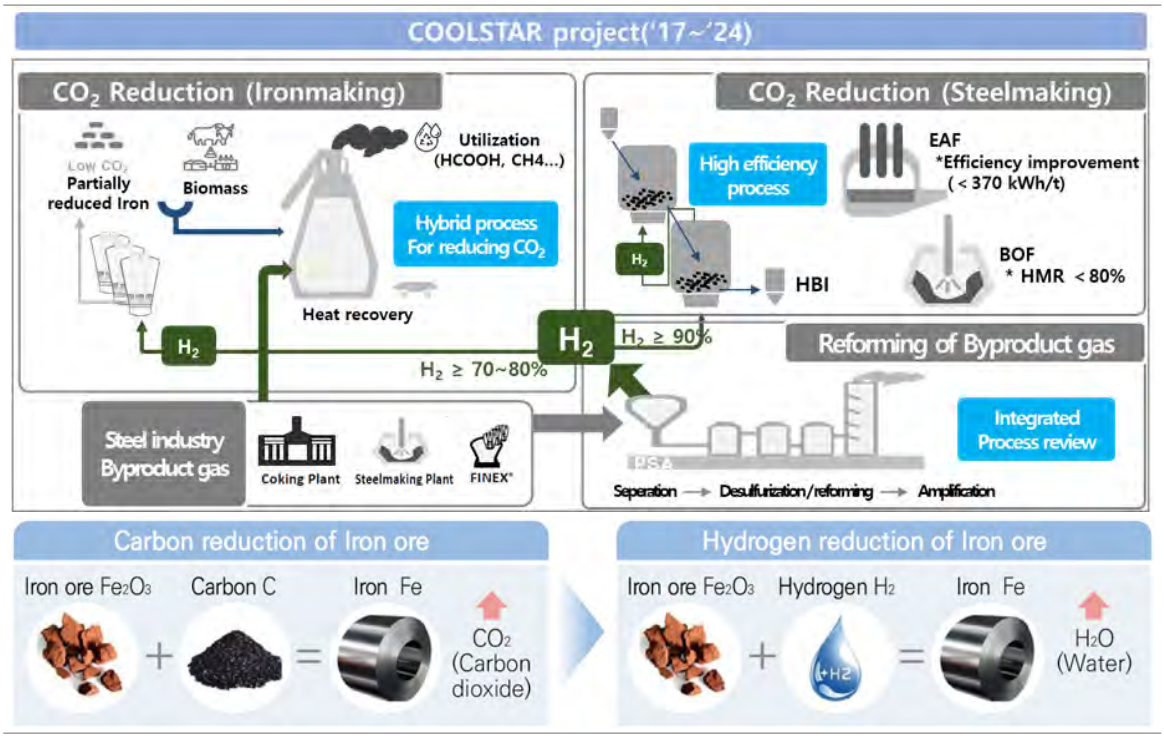
Steelmaking, cement and petrochemical manufacturing are the fundamental industry sub-sectors that have strong forward and backward linkages with Korea's key industries for economic growth – automotive, shipbuilding, construction and semiconductors. They are also energy-intensive sub-sectors that are responsible for a majority share of the industry sector's total GHG emissions.

In these sub-sectors, GHG emissions are inevitable because they are created from chemical reactions in burning coal, limestone and naphtha in major industrial processes. To reduce emissions from these processes, reducing the amount of fuel inputs has been previously suggested, but reducing fuel consumption alone only provides a limited solution. Without a fundamental change in current industrial processes, it is challenging to reduce more emissions. A new solution that introduces new systems utilizing a completely different set of chemical reactions using hydrogen-based technologies, biomass and Carbon Capture and Utilization (CCU) could be a valid option.

In steelmaking, if hydrogen could be used to reduce iron instead of cokes that inevitably emits CO_2 in its blast furnace process, it could dramatically reduce GHG emissions. In fact, the Government and private sector are collaborating to develop basic technologies for hydrogen-using CO_2 reduction steelmaking (i.e., hydrogen direct reduction steelmaking[39)] using carbon as fuel and ingredient) with an aim of demonstrating and developing the technologies from 2025. For a successful application of the technologies, their R&D as well as clean and reliable infrastructural base for a large-volume of hydrogen and energy production is critical.

39) The 2nd energy technology development project is underway from 2017 to 2024 (Ministry of Trade, Industry and Energy, 2017)

[Figure 4-13] Hydrogen reduction steelmaking



Source 2018 Steel Korea (Korea Iron & Steel Association, 2018) and Strategies to Enhance Competitiveness of Steelmaking Industry (Ministry of Trade, Industry and Energy, 2016)

Cement manufacturing process also needs to consider the scope and effect of applying a series of mitigation technologies. Increasing the use of fly ash, slag or pozzolan-blended cement is one option because it could reduce the use of limestone, the main ingredient of clinker in calcination process, which emits high level of GHGs. Alternatively, reducing the production volume of cement itself and instead, increasing the use of recycled aggregate concretes could be considered.

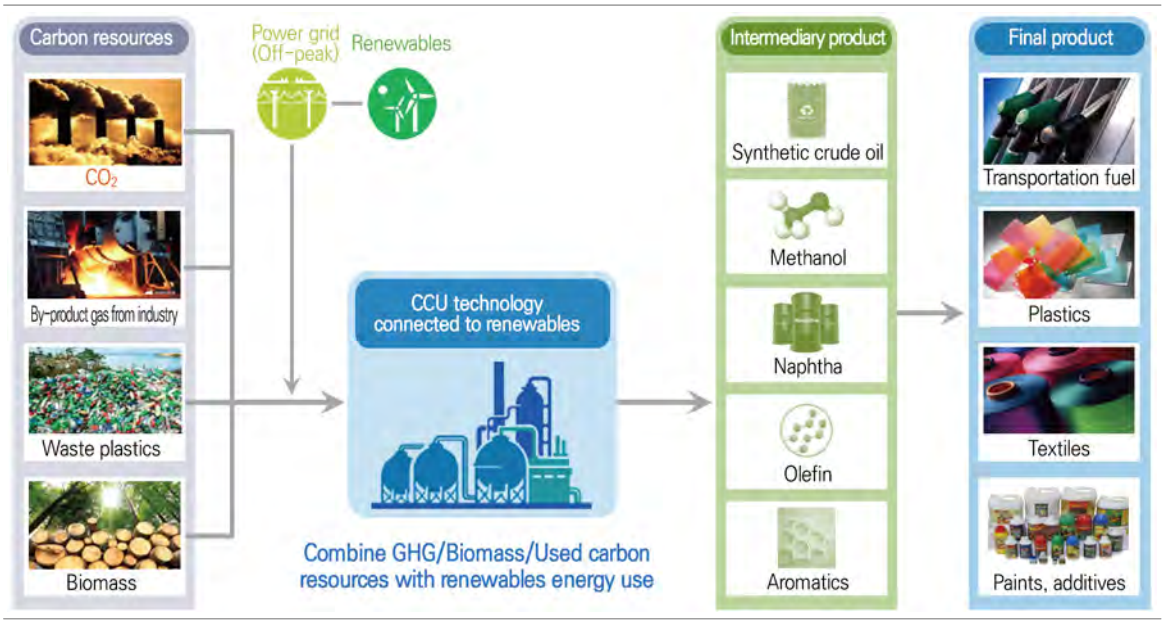
CCUS technology could play a critical role in reducing GHG emissions from high-carbon industries. Steelmaking, cement and petrochemical manufacturing processes are large CO_2 emitting sub-sectors[40], and therefore, if CCUS technology is applied to these sub-sectors, they could prove to be more cost-effective than in other industries.

If petrochemical sector could adopt CCU (Carbon-to-x)[41] technology, it could become a leading technology option for the industrial transition that will lead us towards carbon neutrality. However, CCU technology development is still in initial stage and has low economic feasibility due its high cost. Uncertainty around its commercial deployment is another factor that should be overcome.

40) Steelmaking, petrochemicals and cement production sub-sectors emit 70% of the total emissions from industry sector.

41) Petrochemical processes could use captured CO_2 and hydrogen as a reacting material for methanol synthesis instead of thermal cracking of naphtha, to produce olefin products.

[Figure 4-14] CCU technology for future



Source 「Status and Future of CCUS Technology」(Korea Research Institute of Chemical Technology)

Improving energy efficiency

Improving energy efficiency is another important mitigation option in the industry sector. Korea has been making various policy efforts to enhance energy efficiency and has achieved overall progresses. However, recently energy efficiency has reached a high level, leaving little margin for further improvement and therefore, alternative measures to additionally enhance energy efficiency are needed. In Korea, most energy-intensive facilities in production processes are: boiler, furnace, dryer and motor in that order. More than 90% of total energy consumed by the entire industry sector is used in the above facilities. Mitigation technologies currently available for these facilities are already at mature level and internationally universal options, which therefore, should be considered as a priority in reducing emissions of the industry sector.

Smart factories using Industry 4.0 technologies, i.e. advanced information technologies such as AI and IoT, are vital mitigation options for the future as well. Smart industry refers to the system-wide integration of planning, producing and selling processes of goods using advanced ICTs to ensure efficient distribution of resources and maximization of productivity and energy efficiency. It will not only reduce the use of energy and resources but also cut down on GHG emissions. Once applied, a smart factory system is estimated to reduce 7-10% energy use on average[42]. Therefore, the application of smart factory solutions needs to be completed in most factories and industrial complexes by 2050.

42) Energy Management Working Group, Energy Performance Database 2019.

[Figure 4-15] Smart factory and industrial complex

Conceptual Map of Smart factory

Illustrative Map of Smart Industrial Complex

Source Smart factory conceptual map (Siemens Korea) & Smart industrial complex illustrative map (Korea Industrial Complex Corporation, 2019)

Brining forward circular economy

The amount of material and fuel inputs for producing goods could be dramatically reduced if more wastes are reused and more products are produced sustainably. Much of the wastes that can be reused as input materials are thrown away and if such wastes are reused, it will prove to be cost-effective especially for energy-intensive industries. Already, scrap metals, plastic wastes and used concretes are re-processed and reused as input materials.

The policy for reusing wastes as resources is a highly economical mitigation option that minimizes resource and fuel inputs, which also has an effect of reducing our reliance on future technologies. The Government will improve the infrastructure for waste collection and separation, and establish and tighten industry standards and targets for using recycled materials to encourage the reuse and recycling among businesses.

Increasing use of low-carbon fuels

Replacing fossil fuels (bituminous coal, heavy oil and diesel) used in industrial processes with renewables (waste synthetic resin and biomass) is an option that proves to be effective in reducing emissions and technologically viable. Expanding electrification across the industry sector, based on a carbon neutrality of the power sector, is another major option to be considered in achieving the industry sector's 2050 vision.

However, electrification may not act as a mitigation option due to the GHG emissions generated from producing electricity and the energy loss from electrification itself, and there are numerous industrial processes where electrification is physically impossible. Sectoral characteristics and varying power supply conditions must be fully considered when promoting electrification of the industry sector to achieve further GHG emissions reduction.

Reducing F-gas from industrial processes

Fluorinated gases, or F-gases refer to HFCs, PFCs and SF_6, which are widely used in refrigeration, air-conditioning, and manufacturing processes of heavy electric machines, semiconductors and display devices. The industry sector is the only source of F-gas emissions. Since 2000, the F-gas emission has increased by 32% because the use of HFCs has risen due to the Government restrictions on HCFCs and the rapid development of IT industry, especially in display panels and other electronic devices.

To phase down both production and consumption of HFCs, international community has come together to adopt the Kigali Amendment to the Montreal Protocol. When the Amendment is ratified and comes into force in Korea, 80% reduction in HFCs will be required by 2045. F-gases could be either replaced with materials of lower Global Warming Potentials (GWPs) or destroyed in a high-temperature incinerator. In fact, these options are already in use to reduce refrigerants used in cooling and heating equipment of homes and refrigeration of vehicles. A replacement of SF_6, used for insulation of heavy electronic machines, is under development as well.

Policy efforts are underway at government level to increase the recycling rate of refrigerants and promote their eco-friendly disposal. The Government has put in place a registration system for refrigerant collecting businesses. The Extended Producer Responsibility (EPR) system also requires producers to properly dispose of used refrigerants in their electronic appliances and vehicles when these products are discarded. The Government plans to significantly reduce F-gases emitted from electronic industry processes by expanding the use of heat, catalyst and plasma technologies. The Government will continue to offer policy support to develop highly-efficient mitigation technologies for industrial processes as well as alternative materials to F-gases. The Government will also put in place institutional frameworks and incentives to encourage businesses to establish and implement their voluntary mitigation targets for F-gases.

2.3 Industry sector strategies

Creating a sustainable industry environment

Low-carbon transition and industry streamlining combined with advanced ICTs are the two main elements for innovation in future manufacturing sector. The two elements will fundamentally change the definition and scope of conventional manufacturing which was based on producing goods using fossil fuels. The changed definition and scope of manufacturing and evolving product value chain will emphasize the importance of interlinkage and collaboration among industry sub-sectors.

One-off options will no longer be valid, instead, sustainability will become the top priority in all sectors of our society. To keep up with this changing trend, low-carbon transition and digital transformation should be at the center of industry sector transformation and to this end, decisive actions are needed to promote smart and inclusive innovation in manufacturing sector.

Boosting investment in technology innovation

Commercial deployment of advanced future technologies is the key strategy to achieve the industry sector's 2050 vision. Joint action by the Government and businesses is needed to boost investment in future technologies mentioned in previous sections – i.e., hydrogen direct reduction in steelmaking, CCUS and low-carbon fuels. It is also critical to build up an institutional framework and infrastructure in advance to ensure timely application of developed technologies to industrial processes and sites. For instance, there are several pre-conditions to be met for a successful operation of CCUS technology: safe storage facilities for captured CO_2 emissions; closely linked carbon market system; and a robust framework for the verification of emissions reductions.

Hydrogen direct reduction and low-carbon fuel technologies also require an energy supply system that has ample capacity to provide sufficient amount of hydrogen and renewable energy. Especially, hydrogen reduction steelmaking technology, under development in Korea is CO_2 reduction technology using carbon as fuel and ingredient. Significant investments should be made in developing such innovative technologies with the aim of decarbonizing the entire industry.

Increasing support for energy efficiency improvement

In taking regulatory measures, a balanced approach is a key strategy to create an enabling environment where businesses are encouraged to improve their energy efficiency and motivated to reduce their emissions.

One of the most effective mitigation options currently in use is the Emissions Trading Scheme (ETS). ETS should be used as a tool to incentivize corporate low-carbon activities such as making more investment in improving energy efficiency and reducing more GHG emissions, rather than as a prescriptive regulatory measure that simply controls businesses to purchase permits or adjust production volume. In parallel with the ETS, setting voluntary reduction targets for large-emitters could be another option. If their targets are met, the Government could give them incentives and motivate them to reduce more emissions.

The Government will continuously take measure to tighten energy efficiency standards for boilers, motors, pumps and other major equipment while expanding incentives for retrofitting existing facilities. Factory Energy Management System (FEMS) or the Energy Service Companies (ESCOs) are currently in place but needs to further expand their scopes and targets. Energy Efficiency Resource Standards (EERS) is to be introduced and needs continuous implementation.

3. Transportation

3.1 Status

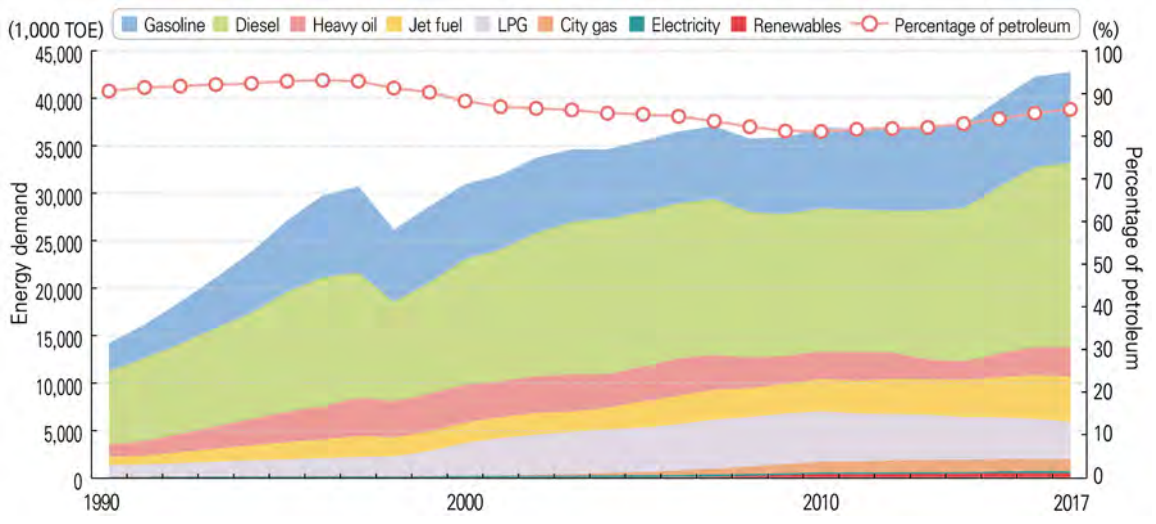
Modes of transportation

The transportation sector offers mobility to people and goods largely in four different modes: on-road vehicles, trains, ships and planes. All these modes of transportation mostly run on fossil fuels, especially on petroleum. 32% of the oil used domestically is consumed by the transportation sector.

<Table 4-1> Fuel use by mode of transportation (as of 2017)

Item	Road			Train	Ship	Plane
	Passenger vehicle	Truck	Bus			
Fuel	Gasoline (37%) Diesel (53%) LPG (10%)	Diesel (99%) LPG (1%)	Diesel (54%) CNG (46%)	Diesel (29%) Electricity (71%)	Heavy oil (51%) Diesel (49%)	Jet fuel (100%)
Energy use (Unit: Thousand TOE)	42,796 (Passenger 78%, Truck 13%, Bus 9%)			343	454	613

[Figure 4-16] Fuel consumption trend by transportation sector

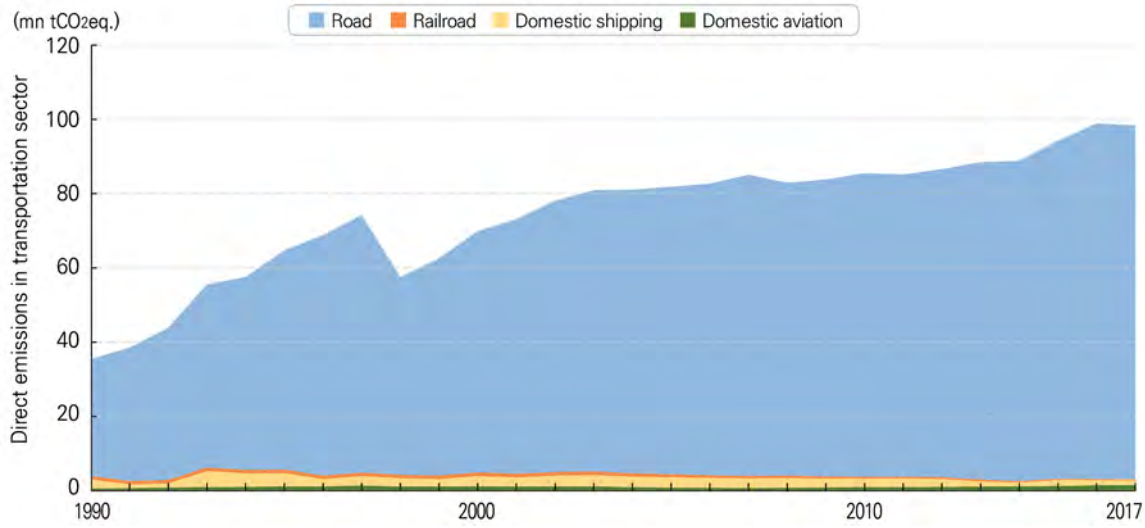


The petroleum-based transportation system is certainly responsible for a large portion of GHG emissions, but its impact on air pollution is far more serious. In fact, as of 2016, NOx and SOx emitted from the transportation sector accounted for 13% of the total Particulate Matter (PM) emissions in Korea, which has emerged as one of the most pressing social issues in recent years.

Emissions by mode of transportation

The transportation sector was responsible for 14% of the total GHG emissions in Korea in 2017. GHG emissions from the transportation sector have increased significantly by 2.8-fold in 2017 from 1990 level due to increased number of vehicles[43], expansion of road networks and expanded freight logistics.

[Figure 4-17] Emissions trend by transportation sector (as of 2017)



The figure 4-17 indicates that the transportation sector's emissions increase rate has been maintained at 4.5% on average per year until 2010, which then, has slowed down to 2.5% from 2012 to 2017. The increate rate has slowed down because overall fuel efficiency has had continuous improvement due to the introduction of GHG emissions and fuel efficiency standards[44] in 2010. Volatility in oil prices has restricted the fuel use, which also has contributed to the slowdown.

43) The number of registered vehicles has increased by 6.6 times from 3.39 million units in 1990 to 22.53 million units in 2017 and the cargo volume has also increased by 6 times from 336 million tons in 1990 to 2,029 million tons in 2017.

44) GHG emissions standards for vehicles: 140 CO_2g/km in 2015 → 97 CO_2g/km in 2020

Since 1990, emissions from on-road vehicles, i.e. passenger cars, trucks and buses, have accounted for more than 87% of total emissions from the transportation sector, and the percentage has increased up to 96% in 2017. Aviation and shipping are only responsible for a small portion of the sectoral emissions, but the aviation industry has recorded a steady average increase rate of 5.5% per year since 2010 while the shipping industry has seen annual average decrease rate of 7.3%.

3.2 Transportation sector's 2050 vision

Introduction of internal combustion engine and electricity system has opened up the era of mass production, symbolized by the 2nd Industrial Revolution. Advancement of internal combustion engine has made a remarkable progress in achieving convenience and mobility for people and goods and shortening travel time. The progress has removed all distance-related obstacles in human history.

Another paradigm shift in the transportation sector, that could be on a par with the 2nd Industrial Revolution, is now underway. This paradigm shift is led by growing demand for carbon neutrality as well as advancement of Industry 4.0 technologies. Unlike the previous modal transformation that has focused on increasing convenience and shortening travel time, eco-friendliness and smart intelligence are the two keys to the ongoing paradigm shift. This modal transformation seeks to move away from the existing petroleum-based mobility and progress towards future mobility characterized by eco-friendly and autonomous vehicles. At the core of paradigm shift is the transformation into clean energy sources with zero-emissions – electricity, hydrogen and biofuels – and into green mobility using such zero-emissions energy sources. Deploying EVs and hydrogen vehicles operating on a clean energy supply system is the key mitigation option in the transportation sector.

Low-carbon transition in the transportation sector will fundamentally change the entire energy demand and supply system in Korea, which highly depends on imported oil. The transition will significantly reduce air pollutants as well, improving people's quality of life and health.

Korea will significantly reduce GHG emissions in the transportation sector from the current level with the main sectoral strategies of increasing deployment of eco-friendly vehicles such as EVs and hydrogen cars, and improving vehicle fuel efficiency. The transportation sector's 2050 vision presented in this section also aims to further accelerate this with four key

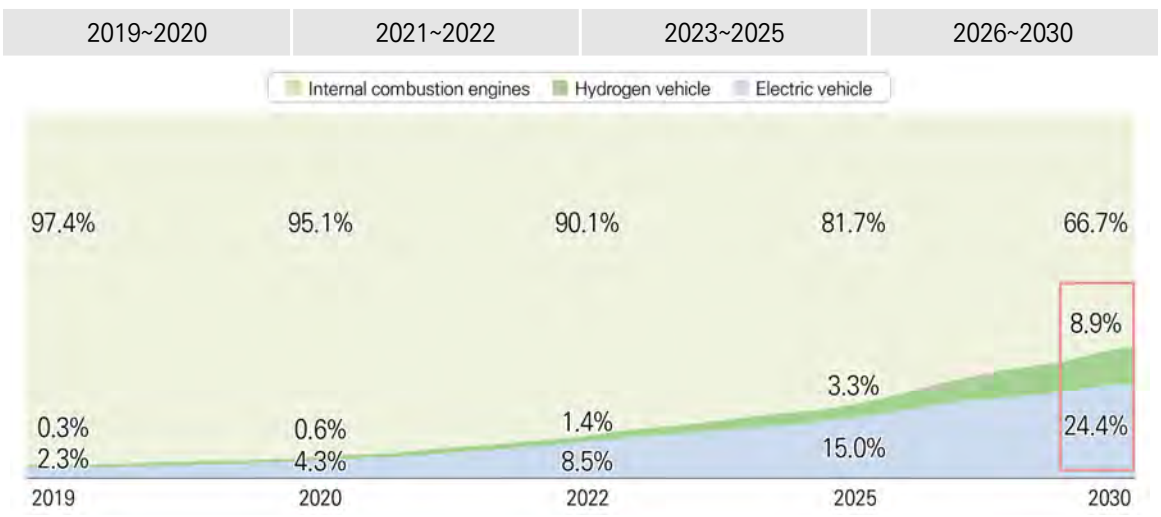
strategies: scaling up deployment of eco-friendly vehicles, increasing low-carbon fuel use, promoting green logistics and managing transportation demand.

Scaling up deployment of eco-friendly vehicles

Electric and hydrogen vehicles are eco-friendly modes of transportation as they are powered by clean energy sources and release zero emissions during operation. Scaling up the deployment of electric- and hydrogen-powered vehicles is expected to be one of the core strategies for the transportation sector, with its high level of contribution to GHG emissions reduction.

Korea has already set an ambitious target of deploying such clean vehicles. According to the target, EVs and hydrogen vehicles will account for 1/3 of new vehicle sales in 2030. The target aims to deploy 3 million units of EV and 0.85 million units of hydrogen vehicle by 2030 and when other types of hybrid vehicles are counted, the number of clean vehicles is likely to increase.

[Figure 4-18] 2030 target for clean vehicle deployment



〈Annual sales target for electric- & hydrogen- powered vehicles〉

(Unit: thousand)

	2019	2020	2022	2025	2030	(Cumulative)
EVs	42	78	153	270	440	3,000
Hydrogen vehicles	6	10	25	60	160	850
Sales percentage	2.6%	4.9%	9.9%	18.3%	33.3%	

Increasing low-carbon fuel use

Biofuels refer to the fuels produced by the mixture of petroleum (fossil fuel) and biomass (biological raw materials) such as bioethanol and biodiesel. These biofuels have a clear mitigation advantage because they could be readily used in existing internal combustion engines. Some modes of transportation are likely to experience difficulty in using electricity or hydrogen as fuels even in 2050, and in such cases, biofuels could serve as an effective mitigation option due to their low-carbon advantage.

Korea adopted the Renewable Fuel Standards (RFS) for transportation fuels in 2015. The standards require a certain level of renewable energy sources to be mixed in transportation fuels, e.g. using 3% or more biodiesels for passenger vehicle diesels. The scope of RFS is planned to be expanded to cover gasoline, ship/jet fuel, and the minimum percentage of renewables is to be increased as well. However, some undermining factors with biofuels still remain. Production of biofuels is known to cause environmental degradation globally and its supply in Korea is still heavily dependent on imported biofuels. The success of scaling up the use of biofuels depends on addressing these factors.

Advancing maritime, aviation and railroad transportation

In Korea, trains are one of the most critical modes of transportation that provide mobility for people and goods with low GHG emissions. Korean railroad infrastructure is already equipped with electricity-powered system, best shown in its city subways and inter-city express railways. As a result, the increase rate of GHG emissions from railroad transportation has been lower than that of passenger numbers carried by rail since the 1990s. As in other sectors, advancing the transport system based on clean energy sources (i.e., electricity, hydrogen, and biofuel) is a core mitigation strategy in aviation and shipping.

Short-term mitigation strategies include expanding Alternative Maritime Power (AMP), increasing the use of biofuel- and LNG-powered ships and improving efficiency through economic operation. Deployment of electricity- and hydrogen-powered aircrafts and ships will serve as a core mitigation strategy in the longer-term. Hydrogen-powered transportation is one of the key pillars of Korea's future mobility. National-level R&D is underway for the commercial deployment of hydrogen-powered trains, ships and drones in Korea by 2030. Such advanced future technologies will help achieve carbon neutrality in the transportation sector.

Managing transportation demand and optimizing vehicle operation

Changing people's behavioral patterns and improving social infrastructure could be an important mitigation strategy as well. The prime example is measures to limit people's driving to reduce energy consumption, and to optimize traffic operation to make energy consumption more efficient.

Strategies to make people drive less include improving the existing mass transit infrastructure, creating a walking and rideable living environment, and expanding shared mobility. Given that half of the entire population in Korea is living in Seoul capital area, policies to promote the use of public transportation in/out of the metropolitan area will solve the problem of traffic congestion during rush hours. Expanding car sharing service in remote areas without access to public transportation is likely to have a positive effect of controlling demand as the service is expected to reduce the number of cars owned and restrain driving.

Meanwhile, optimization of car operation and reduced energy consumption within existing road system could be achieved with the development of a Cooperative Intelligent Transport System[45] and commercial deployment of autonomous vehicles (AVs). Korea has already put in place the advanced intelligent transport system that offers users real-time information on road traffic demands and accidents. The system is closely connected to individual car navigation systems, which help drivers find optimal routes to maximize vehicle operational efficiency.

AVs are another valid opportunity for reducing GHG emissions. The AV technology also aims to maximize car operational efficiency and improve energy efficiency as well. Policies for traffic demand management and optimized car operation are expected to improve energy efficiency, which will contribute to achieving the transportation sector's vision by 2050.

Modal shift

Korea has the world's leading logistics system that enables same-day deliveries of goods nationwide. Evolving logistics system is dynamically changing people's consumption pattern from offline purchases to online shopping, and this trend will accelerate in the years to come. The logistics system in Korea has developed around the road transportation mainly using freight trucks[46], which have consumed a high level of energy resulting in increased

45) C-ITS: Cooperative Intelligent Transport System

GHG emissions and air pollution. Therefore, modal shift of freight from road to low-carbon alternatives such as rail and shipping is necessary to solve this problem.

3.3 Transportation sector strategies

Building up infrastructure for clean vehicles

The price competitiveness of eco-friendly vehicles is currently lower than that of internal combustion vehicles in the market, which means eco-friendly mobility is still in its early development stage and needs policy support to be able to compete with conventional types of vehicle.

Various types of policy incentives and regulations are already available in Korea designed to increase the market penetration of clean vehicles: subsidies for eco-friendly vehicle purchases; minimum purchase requirements for the public sector; and minimum sales requirements for carmakers. The Government will continue to maintain these policy options to provide necessary support for the eco-friendly vehicle market to ensure the market achieves an economy of scale, to make the market self-sustaining and grow further.

Emissions regulation is also an essential strategy to make carmakers increase their fuel efficiency of internal combustion vehicles while selling more eco-friendly cars. Currently emissions regulation is only applied to passenger cars, vans and trucks, but medium- and heavy-duty vehicles will also be subject to emissions regulation in the coming years.

Construction of electric- and hydrogen-fueling infrastructure is another key strategy. If users of eco-friendly vehicles could have an easy and convenient access to EV and hydrogen-charging stations nationwide, it will greatly contribute to their increased market penetration. The Government will continue to scale up its effort to construct the charging station infrastructure. In fact, a significant amount of government funding has been already spent on building the infrastructure: 5,936 EV fast charging stations and 34 hydrogen-charging stations have been already built as of 2019. The Government will also continue to scale up its investment in these infrastructures to achieve the targets of building 10,000 EV charging stations and 310 hydrogen-fueling stations by 2022.

46) Freight transport percentage by transportation mode: Road (91.4%), Railway (1.6%), Aviation (0.01%), Shipping (7.0%) (Statistics by Ministry of Land, Infrastructure and Transport, 2017)

Mobility technology innovation

Even with decisive actions to deploy eco-friendly vehicles and improve social infrastructure to achieve the transportation sector's 2050 vision, there is still a long way to go to achieve the sector's full decarbonization. This means continuous efforts are needed to drive down GHG emissions further, especially by advancing future mobility technologies.

For instance, improved drone capabilities could reduce the demand for deliveries by freight trucks. Electric personal mobility vehicles such as e-scooters or e-mopeds could also play a significant role. Some of the future mobilities such as Urban Air Mobility[47], subsonic capsule trains[48] and hydrails are still in their infancy and therefore it is too early to predict their mitigation effects and technological feasibility. The Government will continue to provide investments in these technologies in the long-term as part of its effort to identify optimal solutions to reduce GHG emissions.

47) The Urban Air Mobility refers to the eco-friendly air mobility services available in urban areas with the function called eVTOL, electric vertical takeoff and landing.

48) High-speed express train driving faster than 1,000km/hour in a subsonic capsule

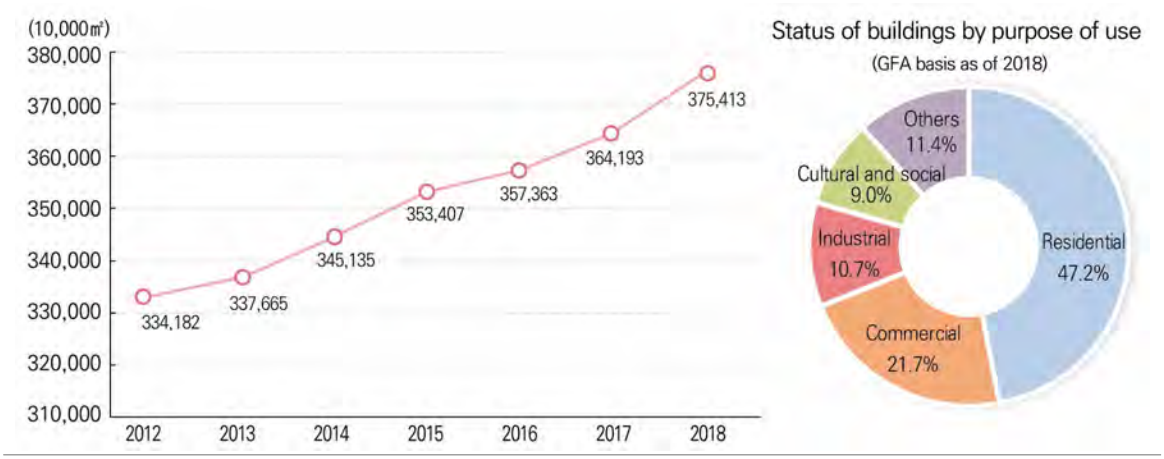
4. Buildings

4.1 Status

Status of buildings

The total number of buildings in Korea recorded approximately 7 million units as of 2018 with Gross Floor Area (GFA) of 3,754,130,000㎡. The number of units and GFA are on the steady rise annually. The figure 4-19 shows GFA percentages of different building types by their purpose of use. Of the total, residential buildings account for the largest share (47.2%), followed by commercial buildings (21.7%) and industrial buildings (10.7%). For residential buildings, apartments take up 61%, indicating apartments are the most common type of housing in Korea.

[Figure 4-19] Status of buildings in Korea



Source Ministry of Land, Infrastructure and Transport

Building sector's energy consumption

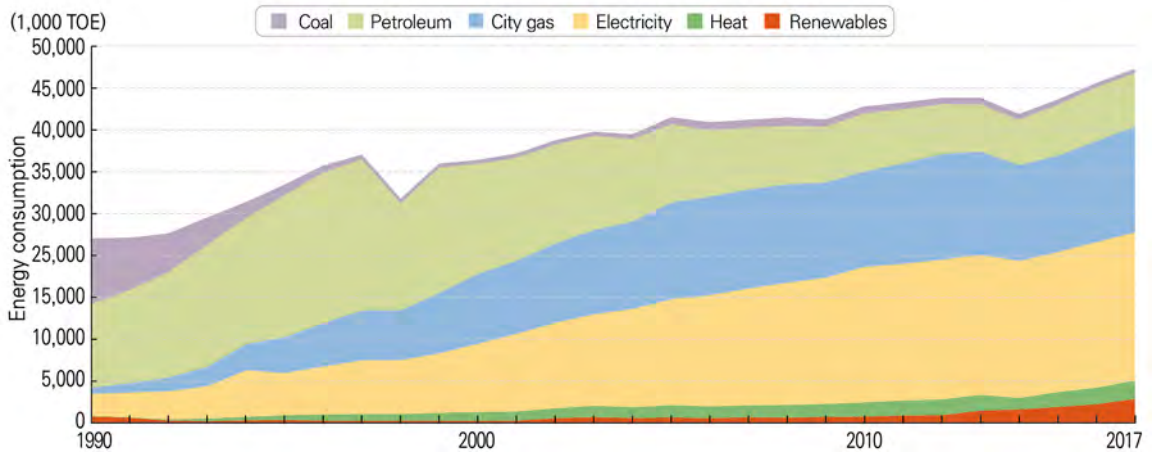
The total energy consumption from the building sector continues to increase due to rising GFA and intensifying extreme weather events, i.e. heat/cold waves. However, building sector's energy intensity (Energy consumption/GFA) has improved steadily[49] due to the effects of the energy saving programs, mitigation policies and improved construction technologies and materials.

49) Energy intensity changes: households 0.014 toe/㎡ in 2012→ 0.013 toe/㎡ in 2018, commercial and public sector 0.022 toe/㎡ in 2012 → 0.020 toe/㎡ in 2018

Energy use patterns by building types shown in the figure 4-20 indicate that the energy use by commercial and public buildings has been rising while energy use by households has been falling gradually. This is attributable to the industry restructuring that has taken place during the period and subsequent expansion of service industries.

Residential and commercial buildings have different patterns of using energy sources as well[50]. Residential buildings mainly use a combination of city gas (46.5%) and electricity (25.9%) whereas commercial and public buildings use electricity (61.9%) as their primary energy source.

[Figure 4-20] Energy use patterns in building sector



Building sector emissions

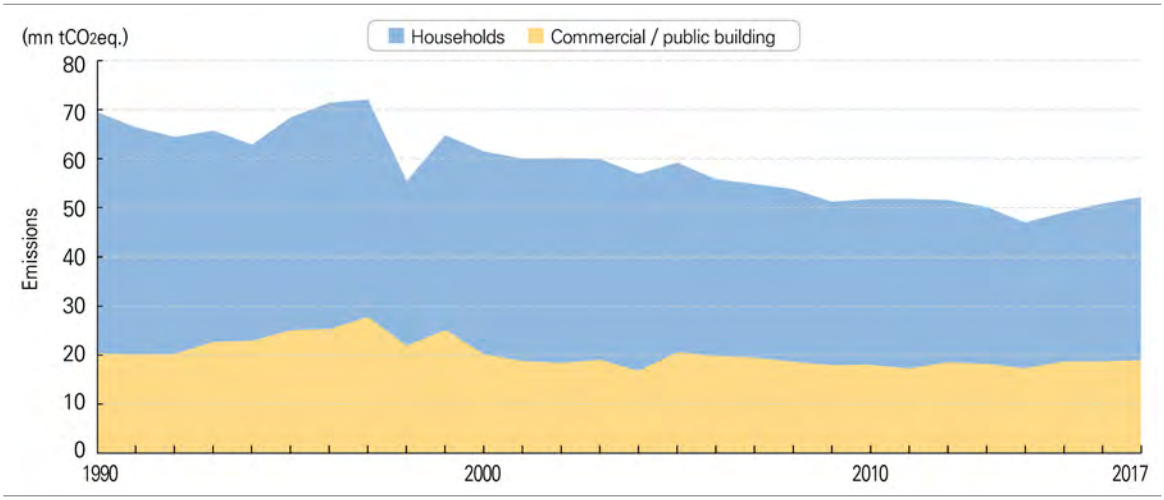
Building sector was responsible for 7% (24% if indirect emissions were included) of Korea's GHG emissions as of 2017. The figure 4-21 displays the rising percentage of commercial/ public building emissions. In contrast, the percentage of residential building emissions has been declining. In 2017, emissions intensity of commercial and public buildings (including indirect emissions) was estimated to be 0.088 $tCO_2eq/㎡$, nearly 2.1-fold higher than that of residential buildings (0.041 $tCO_2eq/㎡$), which indicated that a greater amount of energy was used in commercial and public buildings.

Meanwhile, there has been a surge in direct emissions from the building sector due to its electricity and heat use. Indirect emissions from the sector have increased by 8.8-fold from 1990 level, while direct emissions have decreased by 25%. The sector's indirect emissions

50) Energy use by residential building (as of 2018): power (25.9%), city gas (46.5%), petroleum (14.3%), coal (1.8%), heat (9.8%), renewable (1.7%)
Energy use by commercial and public buildings (as of 2018): power (61.9%), city gas (16.3%), petroleum (14.4%), heat (1.7%), renewable (5.7%)

have risen due to the combination of several factors: increased use of electric home/office appliances, electrification of cooking equipment, and fuel transition for heating from oil/coal to electricity.

[Figure 4-21] Building sector emissions



4.2 Building sector's 2050 vision

Buildings are key elements for creating a living environment, the most fundamental condition of human life. From the perspective of climate change response, buildings consume energy and cause GHG emissions, but they also improve human well-being by protecting people's basic rights to live in properly heated and cooled living environments.

The building sector's 2050 vision aims to lay the foundation for creating an environment where all people could enjoy safe and convenient living and working space and significantly reduce GHG emissions by rationalizing energy use in a cost-effective manner. This vision could be achieved by improving building insulation and air-tightness, minimizing energy use, promoting renewable energy production – solar, geothermal and hydro – and reducing fossil fuel use. Such efforts could make people's living environments cleaner and better.

The Government will seek to harness Industry 4.0 technologies to further improve building energy efficiency and increase deployment of renewables. Different energy use patterns by building types will also be considered to reduce significant amount of GHG emissions. However, city gas[51] used by the building sector for heating and cooking has a nationwide distribution network of pipelines already in place, which makes it difficult to fully

51) City gas penetration rate in Korea: 26.6% in 2000 →31.7% in 2005 → 79.1% in 2010 → 83.7% in 2019

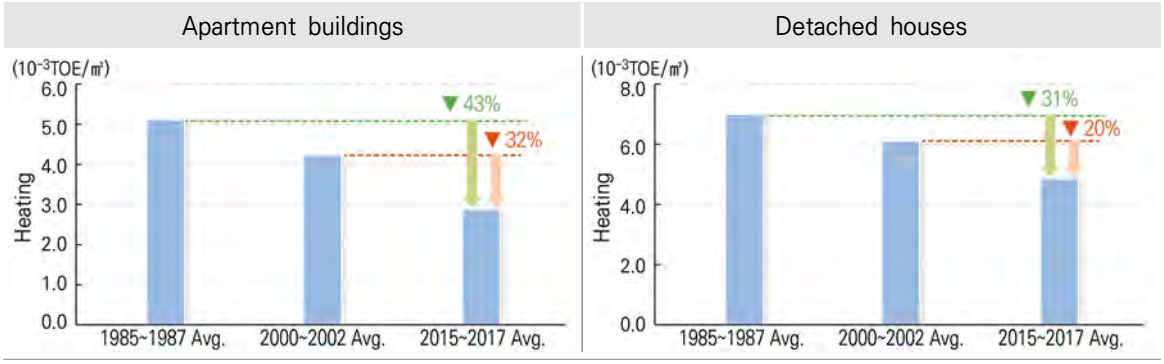
decarbonize. Therefore, emissions reduction level from city gas will be determined when we have a visibility of: the level of technical development and economic feasibility of alternative low-carbon energy sources (i.e., hydrogen); the possibility of deployment of such energy sources; and the level of electrification of equipment used in buildings.

Improving building energy efficiency

Minimizing energy use in buildings, i.e. maximizing building energy efficiency, and supplying low-carbon energy sources for buildings are the most cost-effective mitigation options.

Strategies for improving building energy efficiency have already been implemented and seen remarkable progresses. The comparison between old buildings (built 30 years ago) and newly-built ones shows a stark contrast in the amount of heating energy used per square meter. The figure 4-22 shows that the apartment buildings and detached houses built recently use nearly 43% and 31% less energy compared with old ones, respectively.

[Figure 4-22] Heating energy use by residential buildings per ㎡



Source 2nd Basic Plan for Green Buildings (Ministry of Land, Infrastructure and Transport, Dec. 2019)

The Government has been taking different policy measures for new and old buildings: regulatory measures for new buildings and incentives for old buildings. Newly-constructed buildings are subject to the standards and regulations designed to ultimately phase in zero-energy buildings. All public buildings (GFA of 1,000㎡ or larger) to be built from 2020 will be required to meet the zero-energy building standards and from 2030, the standards will be applied to all public and private buildings (GFA of 500㎡ or larger).

Old buildings are eligible for the government incentives if they adopt green remodeling solutions. Public sector is taking the lead in promoting green retrofitting and remodeling by conducting energy performance assessment on a regular basis. Private sector is also benefited with various incentives such as tax cuts and grants for interest expenses when adopting green remodeling solutions.

Along with the improvement of energy efficiency, using low-carbon energy sources is also critical. Wall-mounted solar panels could contribute to decarbonizing power generation within buildings. Geothermal energy, hydro power and waste heat from power generation and incineration could replace fossil fuels used for heating and cooling of buildings. Improving energy efficiency and enabling passive and active houses is the core strategy to achieve the building sector's 2050 vision.

[Figure 4-23] Buildings using renewables

Solar (Incheon International Airport)	Geothermal (Lotte World Tower)
	
Fuel cell (Eulji Twin Tower)	Heat recovery from treated wastewater (Seonam Water Recycling Center)
	

Deploying highly efficient equipment

Scaling up the deployment of highly efficient home/office appliances and lighting equipment is a major mitigation strategy that can reduce energy consumption while cutting down on GHG emissions. Once built, buildings and houses are difficult to modify or restructure for a long period of time. Considering this nature of building sector, retrofitting old buildings and improving energy efficiency of appliances and equipment used in buildings are highly effective mitigation options.

In Korea, primary home appliances are subject to the energy efficiency standards and labeling scheme[52], which are being tightened gradually by the Government to improve their

52) A total of 33 items (refrigerator, air-conditioner, washing machine, hot & cold water dispenser, rice cooker, LED lamp) are subject to the standards and scheme.

overall energy efficiency. Consumers are also benefited with various government incentives. When consumers purchase home appliances certified to be highly efficient, they are offered a cash rebate, amounting to a certain percentage of a product price. Lighting standards will be also tightened step-by-step to phase out fluorescent lamps[53] by 2027. The Government also plans to increase the market penetration of smart LED lamps to more than 60% by 2040. Smart LED lamps are equipped with sensors and smart controls providing optimal ambient lighting. With the deployment of such highly efficient appliances and equipment, GHG emissions from buildings could be effectively reduced.

Scaling up deployment of smart energy management system

Building Energy Management System (BEMS) mobilizes Internet of Things (IoT), big data analytics and Industry 4.0 technologies in collecting real-time information on energy use within buildings. The BEMS enables automatic control and optimal energy operation, leading to the most efficient energy use.

The BEMS deployment is being scaled up in relation to the zero- energy building standards while deployment of the Advanced Metering Infrastructure (AMI) is being promoted at the government level.

4.3 Building sector strategies

Funding support for green buildings

The measures and systems mentioned in the above could have immediate effects in reducing GHG emissions from buildings, and in the long-term, prove to be economical and cost-effective as they cut down energy costs for building users. However, as retrofitting old buildings and putting in place energy management systems could incur high investment costs in the short-term, the Government's policy support is needed in providing investment incentives for building owners.

The Government is considering various policy options such as providing grants for interest expenses for the investments made to retrofit buildings and expanding tax cuts. The Government also plans to provide funding support for vulnerable populations to promote their welfare in relation to energy supply.

53) Maximum luminous efficacy (lm/W): LED lamps 255 vs. Fluorescent lamp 110

Building up energy big data and promoting their use

In many cases building owners are not necessarily building users, who usually pay for the energy they consume within buildings. Building owners, therefore, lack economic motivation to invest more in improving building energy efficiency.

However, a transparent system that offers accurate information on the building energy efficiency and consumption provides opportunities to make an informed decision for those who are willing to purchase or lease the building. In turn, the system will ultimately motivate the building owners to invest more in improving their building energy efficiency.

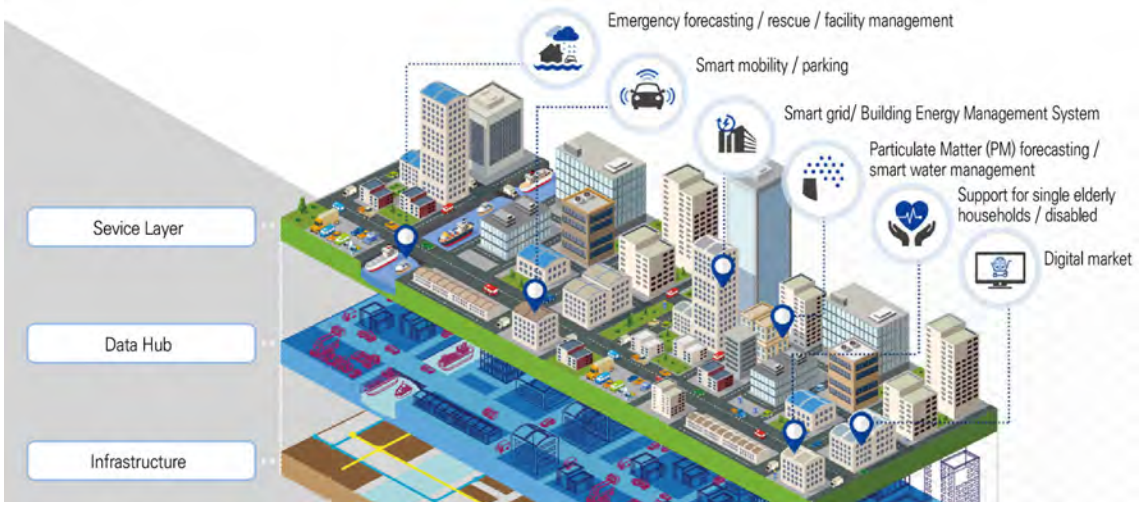
Furthermore, information gap between building owners and users can be addressed by making more energy performance information accessible when leasing buildings, and providing a greater access to building energy big data for the private sector. To this end, the Government will continue to provide necessary policy supports.

Creating future smart city

Cities with closely connected networks of big data and advanced hydrogen technologies, ICT and transportation system could provide numerous opportunities in achieving carbon neutrality of the building sector. Future smart cities tightly linked to advanced ICT are expected to offer real-time information of where surplus energy is being produced so that the extra energy could be used where it is most needed. Hydrogen technology is also an option to be considered when we seek to achieve carbon-neutral heat energy of buildings.

Smart city technologies clearly provide opportunities for emissions reduction at city-wide level beyond the level of individual buildings.

[Figure 4-24] Future smart city



Source Ministry of Land, Infrastructure and Transport, 2018

5. Waste

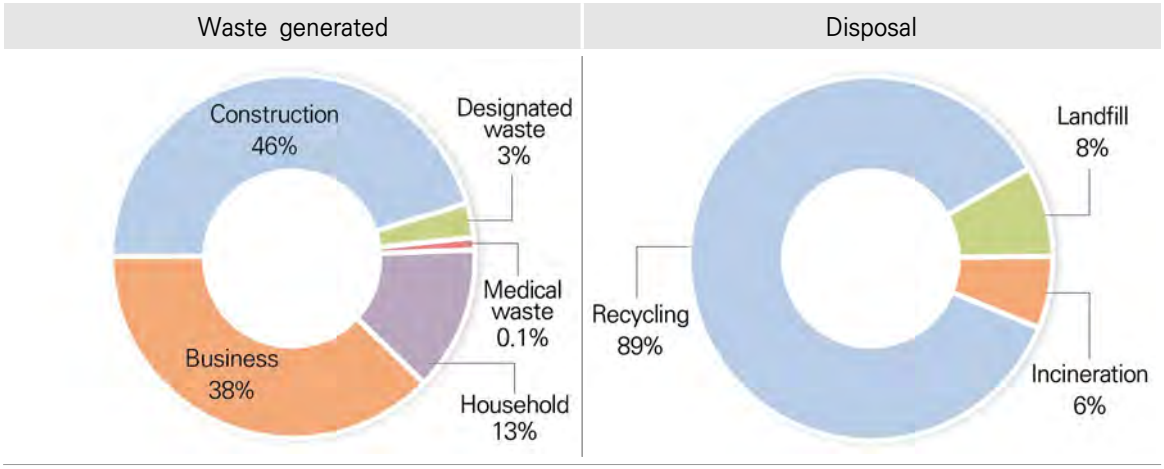
1.1 Status

Waste generated

The waste generated in Korea in 2017 weighed 157.8 million ton, approximately 0.43 million ton/day, indicating 7.5% increase from 0.4 million ton/day in 2012. The increase was mainly due to the changed consumption patterns dominated by online shopping and delivery services. The most notable increase during the same period was shown in plastic wastes from households.

Of the generated waste, 85.4% was recycled, 8.3% was landfilled and 6.1% was incinerated. Recycling rate for construction waste was 98.1% while 80.6% of business waste and 61.6% of household waste were recycled.

[Figure 4-25] Waste generation and disposal (as of 2017)



Waste policy

Korea has been continuously developing its waste policy frameworks to facilitate both waste reduction at source and recycling. Previously our waste management policy mainly focused on safe disposal of wastes, but with the introduction of the volume-based waste fee system in 1995, followed by the Extended Producer Responsibility (EPR) system in 2003, our policy focus has been shifted into waste reduction at source and recycling.

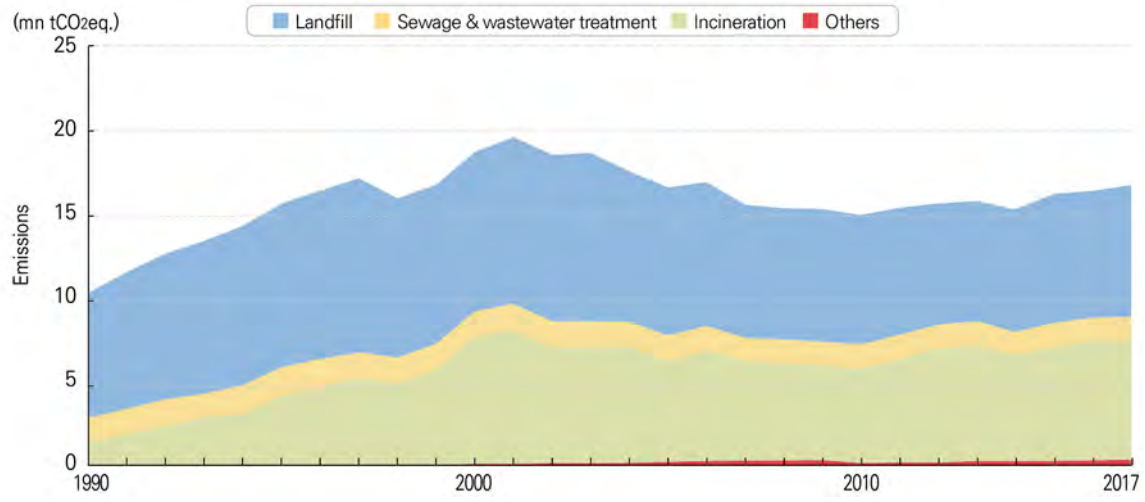
The shifted focus led to the enactment of the Framework Act on Resource Circulation in 2018. The Act aims to improve recyclability of products by taking into account their entire life cycle – from production to disposal – and achieve the transition to a circular economy. In 2018, the 1st Basic Plan for Resource Circulation for 2018-2027 was established and since then, we have been implementing relevant policy measures.

Waste sector emissions

GHG emissions from the waste sector in 2017 recorded 16.8 million tCO_2eq, representing 2.4% of Korea's total GHG emissions. A significant portion of the sectoral emissions (89.9%, equivalent to 15.1 million tCO_2eq) originates from landfilling and incineration. The total GHG emissions from the sector have increased by 69.7% from 1990 level.

Methane is primarily emitted from the decomposition of organic materials in landfills and wastewater/sewage treatment facilities while CO_2 is mainly released from incineration facilities. Unlike other sectors, methane takes up 49.4%, the highest percentage of total emissions of the waste sector.

[Figure 4-26] GHG emissions trend by waste disposal sectors



1.2 Waste sector's 2050 vision and strategies

Over-production and reckless consumption are the cause of waste problems, but they are also the cause of global resource deletion and environmental degradation that are no less serious than climate change.

Therefore, it is critical to fundamentally reduce the amount of waste generated at source and create a virtuous cycle where resources are reused and recycled repeatedly. This could be achieved by maximizing resource efficiency and minimizing resource inputs throughout the entire product life cycle – from extraction of natural resources, to production, distribution and consumption of products, to recycling and disposal of waste.

The waste sector's strategy seeks to identify ways to convert generated wastes into useful materials and reuse them as energy sources to the extent possible. If there are any unrecycled wastes left, they should be disposed of in an eco-friendly manner. The Government is also pushing for the phase-out of plastics, which is one of the core strategies to achieve carbon neutrality. This is our 2050 vision for the waste sector that could serve as the most eco-friendly and cost-effective mitigation option for our transition towards a circular economy.

Waste reduction at source

The top priority to achieve this vision is to reduce resource inputs and waste generation throughout the entire life cycle of products. By doing so, we aim to achieve the decoupling of waste generation from economic growth.

To this end, production flows need to be optimized by each production process to minimize resource inputs and energy losses. All production processes must be streamlined in an eco-friendly way to ensure all generated by-products are reused on the site to the full extent possible. The business entities that consume large quantity of resources and generate large amount of wastes will be subject to the target management system. The system will apply tightened targets for reducing waste at source, increasing resource productivity and using recycled material inputs.

A new type of supply chain will be created with its focus on reusable packaging. The new supply chain aims to dramatically cut down on disposable packaging materials and promote the use of reusable packaging in B2B and B2C transactions. Once used, the reusable packaging materials will be collected for reuse.

To reduce waste generated from the consumption stage, products should be designed easy to repair and durable. Repair instructions should also be provided for users in more detail. Single-use plastics will be phased down from the stage of production to consumption. The Government is planning to provide local instruction services for repair, reuse and upcycling to minimize the amount of waste thrown away after a single use.

Promoting recycling: creating added values from wastes

Our vision for the waste sector is that once generated, wastes should be kept in a circular cycle where they will be repeatedly reused and recycled to the full extent possible. This will allow us to reduce extraction, production and use of natural resource and energy and cut down on incineration and landfilling of wastes. To achieve the vision, product recyclability should be considered first and foremost from production stage, e.g., designing colorless PET bottles that are easy to recycle. The Government plans to establish design standards targeted for each product's purpose of use and for each product item to enhance resource recyclability.

It is also imperative to make waste separation, collection and sorting more efficient to ensure that materials to be recycled maintain proper quality. Waste separation standards should continue to be tightened, taking into account changing physical properties of wastes generated, driven by evolving socio-economic structure. The Government plans to scale up investments in developing sorting technologies and expanding related infrastructure. The Government will also set up an incentive-based system that offers different level of policy supports depending on the quality of sorted materials.

It is also important to build up a circular system that mandates producers to use a certain percentage of recycled content as input materials when manufacturing new products. To this end, first and foremost, the Government will work on improving the EPR system, and in the mid-to long-term, set mandatory percentages of recycled materials in consideration of characteristics of different manufacturing types. Public sector will be encouraged to purchase recycled products and consumers will have more choices to choose from as more recycled products will be released on the market. A recycling cluster dedicated to large-scale R&D, demonstration and prototype production should also be created to foster recycling industries and technologies. Moreover, new types of wastes are to be generated with the rapid advancement of Industry 4.0 technologies and renewable energy. They should be managed by the public sector within a safe and reliable disposal system. The public-private partnerships will also be followed to build a recycling system that creates high added values from these new types of wastes.

Eco-friendly disposal of waste

Wastes that are unrecyclable should be disposed of in the eco-friendliest manner possible so as to reduce GHG emissions. Currently direct landfilling is banned for food waste only, but combustible waste will also be banned from direct landfill disposal. Only the residues left from sorting and incineration will be allowed for direct landfilling. We will also set up eco-friendly landfill standards to enable low-carbon landfill management. Landfill facilities of a certain size will be required to install methane recovery facilities to increase on-site energy production.

Waste incineration will not simply be a waste-burning process, but instead act as an energy production base. The energy generated from incineration process will be connected to district heating system and hydrogen production/using sites for its full use. The Government will continue to support the development of carbon capture or sequestration technologies applicable to incineration process, and update the incineration facility standards to mandate on-site application of these carbon reduction technologies.

One of the core materials anticipated to be used in the future is bioplastics. Although the base for their production and use is not in place yet, bioplastics are expected to reduce the demand for synthetic plastics and cut down on waste generation at source. For the ultimate replacement of synthetic plastics with bioplastics, R&D on bioplastic technologies should be continuously conducted while marketing efforts to diversify their lines of products should be made.

6. Agriculture, livestock farming and fisheries

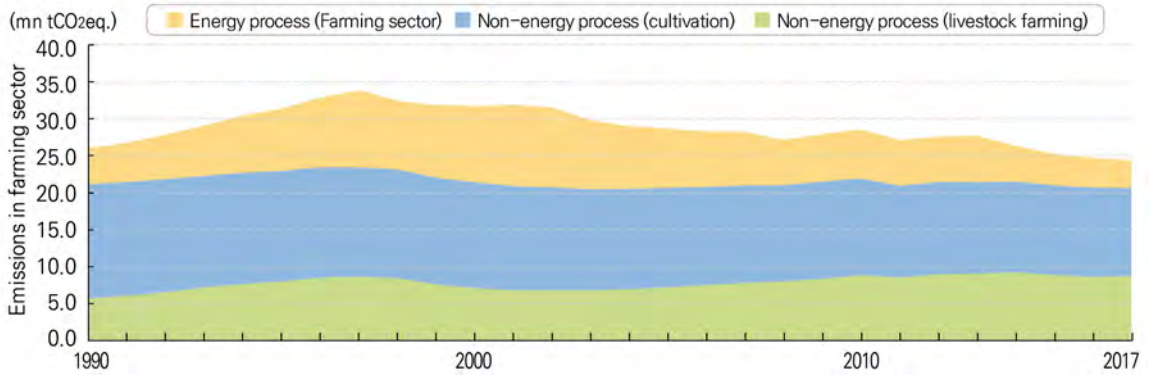
6.1 Status

Farming sector emissions

Agriculture, livestock farming and fisheries sector (collectively referred to as "farming sector" in this section) contribute 3.4% (including emissions from using energy) to the total GHG emissions in Korea, which is 24.1 million ton of CO_2eq. Of the total emissions from the farming sector, agriculture and livestock farming sectors are responsible for 88.6%, which mainly comes from non-energy processes such as crop cultivation and livestock farming with main emissions being CH_4 and N_2O. Fisheries sector emissions, accounting for 11.6% of total farming sector emissions, are mainly from energy process which involves consumption of energy by fishing boats and farms.

The total emissions from the farming sector were down by 7% in 2017 compared to 1990 level. During the same period, non-energy processes saw 3% decrease in emissions while energy processes experienced 23% decline. Especially for non-energy processes, the share of emissions from crop cultivation decreased from 73% to 58% while that of livestock farming increased from 27% to 42%. This trend is mainly due to the continuous decrease in rice cultivation area[54] in contrast to the increasing number of cattle and swine[55][56].

[Figure 4-27] GHG emissions from the farming sector (by sub-sector)



54) Change in rice cultivation area (ha): 1,251,000 in 1990 → 777,000 in 2017 (National GHG Emissions Inventory Report, 2019)

55) Change in number of cattle: 1,579,000 in 1990 → 3,015,000 in 2017, Changes in number of swine: 4,412 in 1990 → 10,514 in 2017 (National GHG Emissions Inventory Report, 2019)

56) Crop cultivation involves anaerobic decomposition of organic materials that emits CH_4. Usage of fertilizer/manure and crop residues emit N_2O. Livestock farming involves enteric fermentation releasing high level of CH_4. Manure processing also emits CH_4 and N_2O.

6.2 Farming sector's 2050 vision and strategies

Looking ahead, changing lifestyle and dietary patterns are expected to have impact on the food demand. Meat consumption, in particular, is expected to grow continuously for a considerable period.

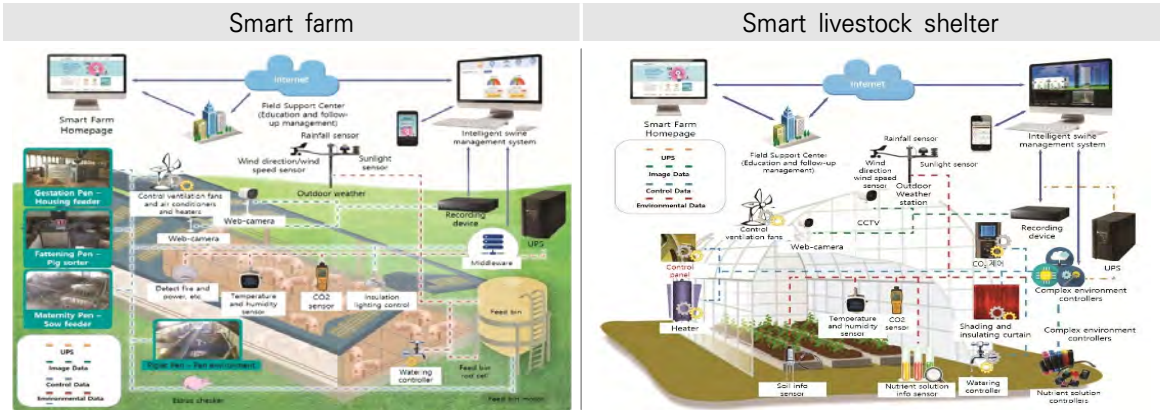
Most of the GHG emissions from the farming sector is attributable to the biological reactions taking place from food production processes. Therefore, it is impossible to remove the sector's entire GHG emissions. Still there are many mitigation options available for use. Some of the options include: irrigation of rice paddy fields; low-input farming; coarse fodders and forage mixtures that emit low methane; and the use of manure as resources. All of these options are expected to reduce GHG emissions. We also expect to reduce CO_2 emissions from energy processes of the farming sector with greater use of clean energy sources and energy saving facilities.

Transition to smart farming

Industry 4.0 technologies including advanced ICT, big data and IoT provide the farming sector with opportunities to reduce further GHG emissions as well. Smart farms and smart fish farm clusters are the prime examples. ICT connected to existing farmlands and facilities such as greenhouses, livestock shelters and fish farms could help minimize inputs (i.e., energy sources, fertilizers, water, etc.). Moreover, ICT-enabled automation on smart farms could improve farming productivity.

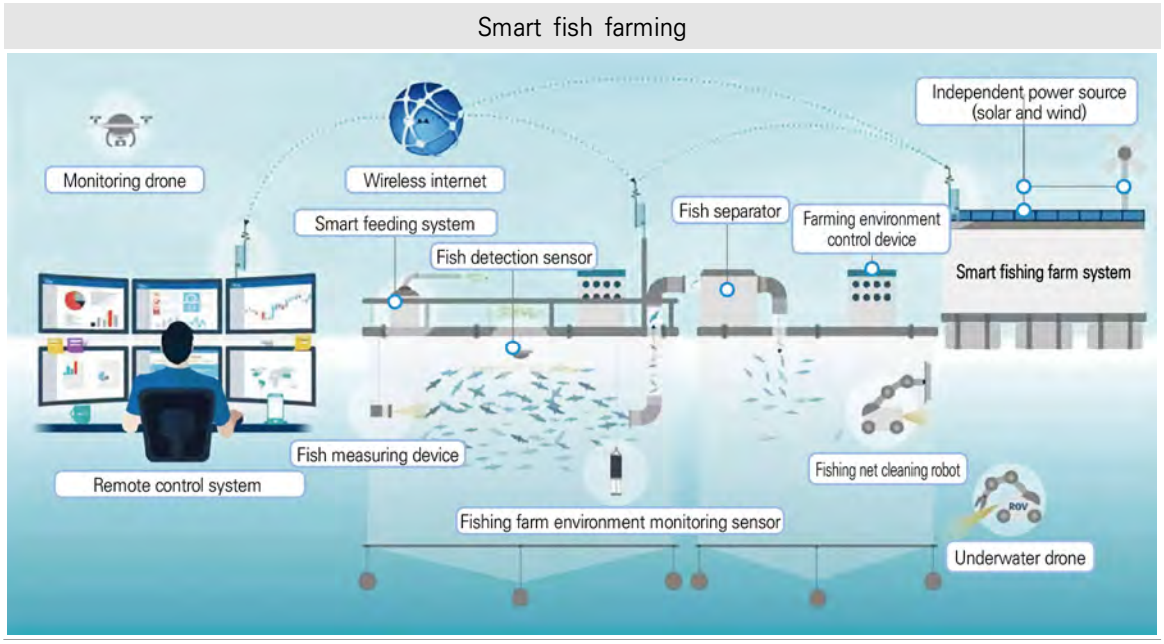
Korea is employing a growing number of such smart technologies in the farming sector. The Government plans to deploy 7,000 ha of smart farms and 5,000 units of smart livestock shelters by 2022, along with three smart fish farm clusters on the coastal major hubs of our surrounding seas by 2023.

[Figure 4-28] Smart technologies in farming sector



Source Ministry of Agriculture, Food and Rural Affairs

[Figure 4-29] Smart fish farming technology



Source National Institute of Fisheries Science

Scaling up development & deployment of low-carbon farming practices

To reduce GHG emissions originating from crop cultivation and livestock farming, it is essentially important to develop and deploy low-carbon agricultural technologies and practices. The prime examples of such farming practices are water management in irrigated rice paddies and low-methane fodders that improve livestock enteric fermentation, both of which reduce methane emissions. For farmers to adopt such practices in farming, related education programs and technological supports should be continuously provided for them. There are other options worth considering: low-input farming; development of soil carbon storage methodologies and management; and replacement of fossil fuel with clean energy sources. The Government plans to pursue R&D on these low-carbon farming practices and also expand education and support for them for wider application.

Participatory policies for farmers and consumers

To accelerate the low-carbon transition in agriculture and rural areas, enhanced mitigation efforts in farming sites is essential. To encourage such efforts, Korea has operated an incentive-based emissions reduction program for farmers since 2012. The number of participating farms is gradually increasing.

Agricultural produce, meats or dairy products produced using the farming practices that minimize inputs, i.e., fertilizers, pesticides and farming supplies, are certified as low-carbon products and the Government is stepping up its effort to scale up this type of certification program.

Consumers should also do their part by generating less food waste and changing their dietary habits to reduce their carbon footprints in their daily life. Public awareness-raising programs are needed to change their consumption patterns and lead them towards a low-carbon lifestyle.

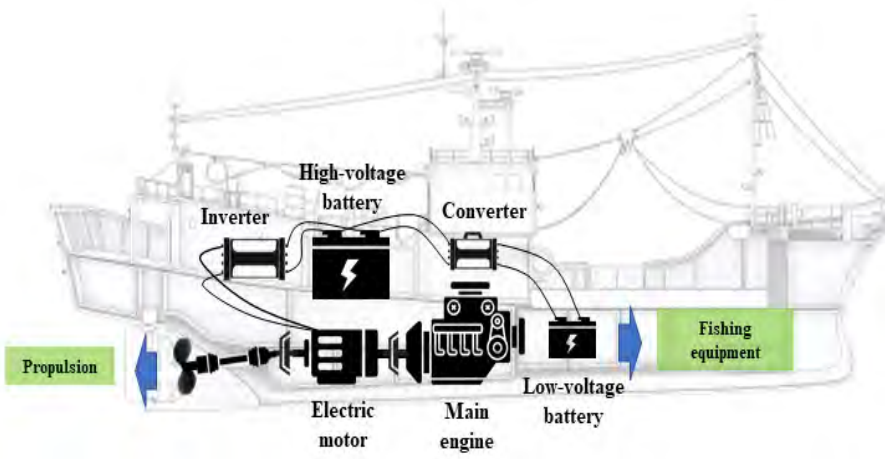
Scaling up deployment of eco-friendly energy

Replacing fossil fuels with low-carbon energy sources in the farming sector is the most feasible mitigation option with largest emissions reduction potential. Turning manure to energy, deployment of solar energy, and using geothermal heat pumps are available options that can reduce the use of fossil fuels. Using LED lamps and thermal curtains are also useful as they increase energy efficiency.

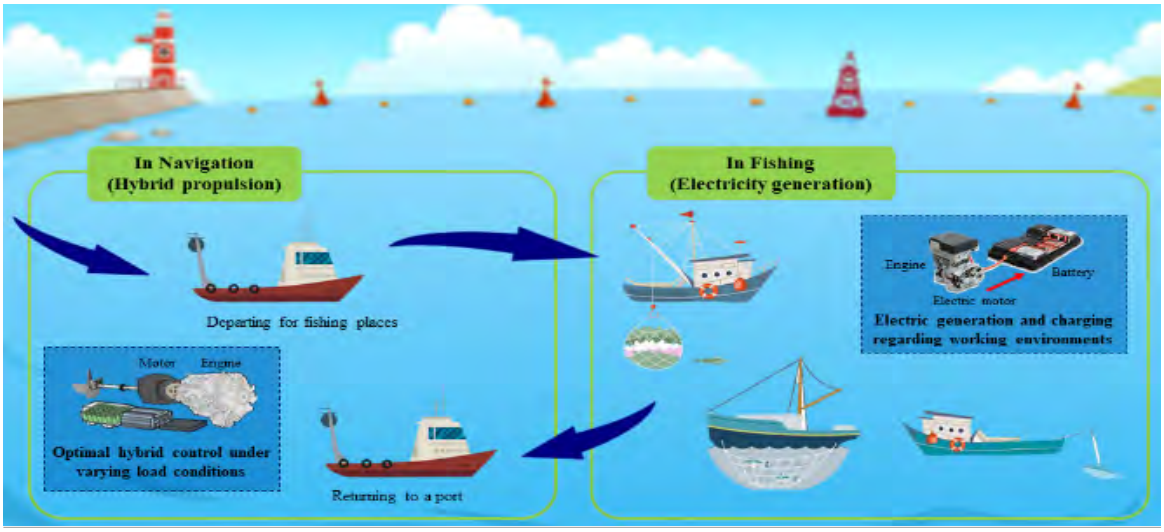
Environment-friendly fishing vessels powered by electricity and hydrogen saves energy use and reduces GHG emissions from fishery production. Developing these vessels is an important option to put in place a low-carbon production structure that will help us achieve a sustainable fishing and build climate resilience. The Government will continue to encourage the deployment of such fishing vessels going forward.

[Figure 4-30] Energy saving eco-friendly fishing vessels

How to develop eco-friendly vessel engine



How to operate eco-friendly fishing vessels



Source Ministry of Oceans and Fisheries

Processing fishery products requires a large amount of energy as it involves refrigeration/ freezing and high-temperature heating. The fishing industry will be encouraged to adopt energy saving options such as reusing air-source heat from seaweed processing plants.

Moreover, the Government plans to bring in digitized automation system based on smart technologies to fishery processing factories. The system will make factory automation possible and help those factories maintain the best temperature and humidity for processing and storing optimal quantities of foods. Fishery processing factories with such technologies, or smart factories, will achieve optimal production and most efficient energy use.

We need more of the success stories of farming and fishing communities using solar, wind and other eco-friendly energy sources. The stories will serve as a model for future lifestyle, balanced regional development and eco-friendly energy transition. They will be exhibited as best practices of combining energy transition with local development. They will also help us be prepared for potential social changes, e.g., changing industrial site locations and population migration.

Using by-products as resources for bio-industry

Oyster shells are highly valued recyclable by-product, produced in the process of producing, consuming and distributing fishery products. If they are used as a replacing material for limestones, GHG emissions could be reduced. When the shells are used as input materials for bio-industry (i.e., foods, pharmaceuticals and cosmetics), it could also reduce the quantity of fishery by-products. Efforts to foster new industries using such by-product need to be made.

7. Carbon sinks(LULUCF sector)

7.1 Status and outlook

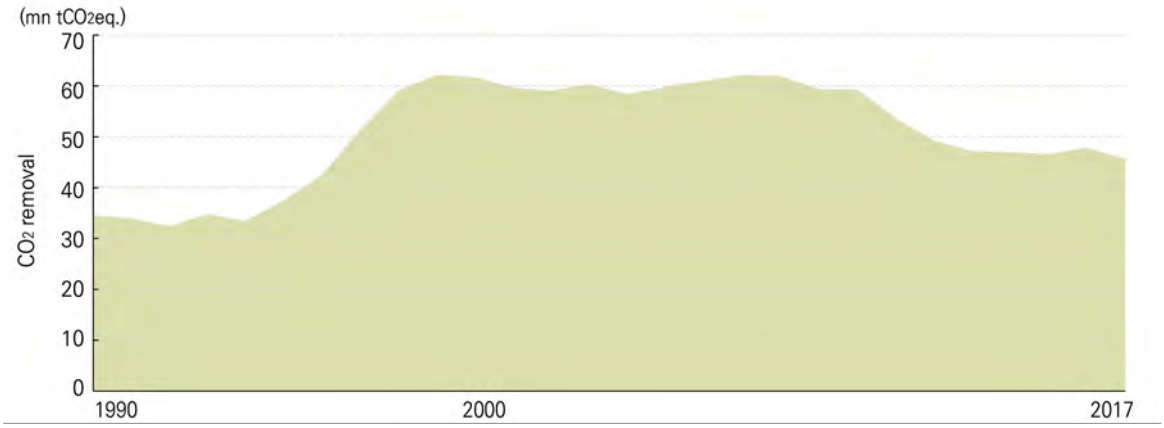
Status of carbon sinks

Lands in Korea are divided into different categories by their purpose of use: urban areas, croplands and forestlands. These land types have different locations, histories and surrounding circumstances. Depending on how they are used, some types of lands emit GHGs, but most lands with any type of vegetation covers absorb CO_2 through photosynthesis.

Photosynthesis by plants is by far the most environmental way of removing CO_2 compared to any man-made CO_2 removal technologies. Its cost-effectiveness is also high. Forests make up 63% of the total land mass in Korea. Our forests had been seriously damaged during the Japanese colonial rule and the forestation rate declined down to 35% in the mid-1950s. But we have successfully restored our deforested lands with large-scale national reforestation program in the 1970s and 1980s. Success from the reforestation program has led to today's high percentage of forestlands, which have made it possible for our land to become a net carbon sink, absorbing more carbon than it emits despite urbanization and large-scale land development in its modernization process.

Since the national reforestation program in the 1970s, CO_2 removal by forests has been on the steady rise until its peak in 2000. Since then, CO_2 removal has been gradually decreasing due to aging forests and changing forestland use that have followed. In 2017, CO_2 removal by forest recorded 45.7 million ton CO_2eq, offsetting 7.4% of energy sector CO_2 emissions.

[Figure 4-31] Carbon removal by forest

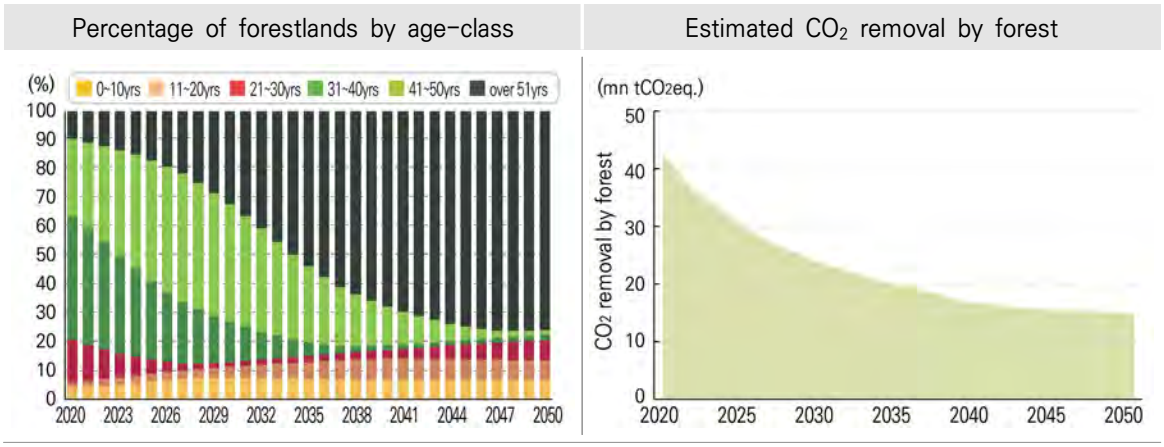


Outlook for carbon sinks

Most forests of today in Korea are the result of massive tree-planting national program in the 1970s and 1980s. Therefore, most of the trees are currently in 3-4 age-class[57], whose net growth volumes are the highest in their lifespan. Looking ahead, as trees and forests will age, the percentage of forestlands at age-class 6 or older, whose net growth volume declines rapidly, will increase. The National Institute of Forest Science estimates that the percentage of forestlands at age-class 6 or older will increase from 10.2% in 2020 to 32.9% in 2030 and accordingly, the annual average net growth volume per hectare will decrease from 4.3㎥ in 2020 to 2.6㎥ in 2030 and further down to 1.9㎥ in 2050.

To reverse this decreasing trend of net growth volume, more timber should be produced from older trees so that older forestlands can be replaced with younger forestlands. Unless the demand for domestic timber increases dramatically, however, the forest age-class disparity and annual growth volume are unlikely to improve. Considering the current state of forests and timber production plans, the carbon removal is estimated to decrease by 30% from the current level by 2050. Potential decrease in forestlands driven by growing urbanization is also expected to have adverse impacts on carbon sinks.

[Figure 4-30] Percentage of forestland by age-class & carbon sinks forecast



7.2 LULUCF sector's 2050 vision and strategies

Forest sector takes up a majority share of the total carbon removal in Korea. Innovative forest management, therefore, is a key to improving aging forests, promoting the use of wood products/timber and increasing carbon stocks.

57) 10-year basis age structure of a forest. Age-class 1 includes 1-year to 10-year old trees and age-class 2 includes 11-year to 20-year old trees.

On the production side, the priority focus should be on forestation and forest management to gradually increase their carbon absorption capacity. On the consumption side, the use of domestic timber should be increased to create a virtuous cycle of using forest resources.

Expansion of forests

Expansion of forests is the most important strategy for increasing carbon sinks. Afforestation is a process of planting trees in an area where there was no tree before whereas reforestation is to re-create forests in an area where its land use was converted.

Korea has already succeeded in expanding forestlands and there is nearly no land left available for either afforestation or reforestation. However, the Government plans to increase carbon sinks including through creating urban green spaces for recreational use, restoring degraded forestlands and tree-planting in underutilized lands (i.e., marginal farms[58] and settlements[59]).

Maintaining carbon sinks

Forest management refers to the practices seeking to maintain the carbon removal to the highest level possible for continuous and sustainable maintenance of forestlands. In Korea we have two options for forest management: changing tree species, and the so-called “healthy forest program.”

Korea has the issues of forest age-class disparity and high percentage of privately-owned forestlands. Under such circumstances the practices mentioned in the above has a significant role to play. As a result of implementing the two options in Korea, nearly 170,000 ha of trees were harvested annually between 2015 and 2019. The Government plans to further increase the areas for tree species change and encourage forest owners to take part in their forest management.

Changing tree species refers to the harvesting of forests damaged by pests, aging trees, or poorly stocked stands and replacing them with tree species absorbing a high level of carbon. After changing tree species, carbon removal level generally decreases in the short-term, but in the end, replaced tree species contributes to the increase in carbon sinks. Healthy forest program involves practices such as pruning, ivy removal, and harvest by thinning, all of which aim to keep forests healthy by taking into account their age and current status. In

58) Marginal farms are lands with little agricultural value and low productivity.

59) Settlements are urban lands where forests can be created. Green spaces, stream-sides, and roadsides are the examples.

the short term, the program has positive impact on the growth of forests while in the long term, produces quality timber and contributes to increased carbon sinks. Currently the forestlands managed by this 5-year program (currently in phase 4 of 2019-2023) is estimated to be 1.1 million ha.

Expanding timber supply

With aging forests, Korea sees its annual forest growth volume dwindling and the forest age disparity greatly limits sustainable management of forest resources.

Increasing tree-harvesting volume for greater timber supply could press down carbon sink level in the short-term, but could address the forest age disparity, foster tree growth and help achieve sustainable forestry in the long-term. As timber is a carbon-neutral resource, the more we use wood products, the greater GHG emissions are reduced. Use of forest biomass produced from sustainable forest management also contributes to reducing GHG emissions as well as addressing renewable energy intermittency.

Some of the most durable wood products last for 100-200 years and carbon storage function is another feature of wood products as they lock in CO_2. Timber products could also have a carbon reducing effect as they could replace carbon-intensive materials such as steel and concrete[60].

7.3 Other carbon sinks

There are other types of carbon sinks such as coastal wetlands.

Blue carbon is a newly emerging carbon sink option. Blue carbon refers to the carbon absorbed by seagrasses in coastal ecosystems through photosynthesis, as well as the carbon captured in sediments in terrestrial and marine ecosystems.

Marine ecosystem absorbs carbon 50 times faster than terrestrial ecosystem does. In water, decomposition of organic materials is slow due to its anaerobic conditions. Therefore, carbon deposited in plants is not degraded and remains intact for a long time.

60) Timber processing emits 1/350 of GHGs emitted from steelmaking, and 1/1,500 of aluminum production. The GHG emissions from building a wooden house are 1/4 of those from building a reinforced concrete house.

Korea has the world's 5th largest mud flat areas (2,482㎢) and has a great potential in blue carbon. Recent coastal development and environmental degradation, however, are posing threats to coastal environment and marine habitats, which require an urgent measure to restore them. The Ministry of Oceans and Fisheries has a plan to restore 20 mud flats with the total length of 4.5 kilometers by 2025[61]. The restoration project will be further scaled up going forward. A total of KRW 10 billion has been invested in the 5-year R&D project from 2017, which will deliver statistics on the current status of domestic blue carbon and develop technologies to measure and verify the amount of blue carbon. Looking ahead, we expect blue carbon from coastal wetlands to be included in the national GHG inventory to help achieve Korea's NDC.

61) The 2021-2025 basic plan for mud flat management and restoration (Ministry of Oceans and Fisheries)

2050 Carbon Neutral Strategy of the Republic of Korea

towards a sustainable and green society

Chapter 5

Innovating Implementation Base

1. Policy innovation

1.1 Assessing NDC implementation

Importance of implementation assessment

The Paris Agreement provides flexibility for all Parties to set their voluntary NDCs in the light of their different national circumstances. The Agreement also highlights transparency in all its procedures, especially in measuring, communicating and verifying GHG emissions and progresses in implementing NDCs.

For the achievement of the NDC pledged to the international community, we have built a mechanism to assess our implementation of NDC in the 2nd Basic Plan on Climate Change Response which took effect in 2020.

<Table 5-1> Government-wide implementation assessment mechanism[62)]

Central Gov.

- Set indicators and targets by sector & task
- Collect & submit annual assessment data

	Steering Committee	Power	Industry	Building	Transportation	Waste	Public sector	Farming	Forest
Led by	ME OPC	MOTIE	MOTIE	MOLIT MOTIE	MOLIT MOTIE	ME	ME	MAFRA	KFS
Collaborated w/	Related ministries	-	MAFRA, MOLIT, MOF	-	ME, MOF	-	MOLIT MOTIE	RDA KFS	-

⬇

GIR

- Prepare the synthesis report for implementation assessment
  - Establish and operate an expert working group for the synthesis report
  - Support the work of preparing the synthesis report done by national research institutes(KEEI, KICT, KOTI, etc.)

⬇

Committee on Green Growth

- Manage and oversee the entire mechanism
- Monitor and review assessment data and offer policy advice

Source 2nd Basic Plan for Climate Change Response (October 2019)

62) The acronyms in this table stand for the following government ministries and agencies:
ME: Ministry of Environment
OPC: Office for Government Policy Coordination
MOTIE: Ministry of Trade, Industry and Energy
MAFRA: Ministry of Agriculture, Food and Rural Affairs
MOLIT: Ministry of Land, Infrastructure and Transport
MOF: Ministry of Oceans and Fisheries
RDA: Rural Development Administration
KFS: Korea Forest Service
GIR: Greenhouse Gas Inventory and Research Center
KEEI: Korea Energy Economics Institute
KICT: Korea Institute of Civil Engineering and Building Technology
KOTI: Korea Transport Institute

Synthesis report for implementation assessment

A series of assessments are conducted on how mitigation policies in Korea have been implemented in nine sectors: energy supply (electricity & heat), industry, transportation, building, waste, public sector, farming, forest and CCUS. A total of 81 indicators have been developed to measure implementation progress in each sector.

Besides the national GHG inventory data, the report includes estimated potential emissions to ensure higher objectivity. For the preparation of the synthesis report, each ministry collects information on their respective targets, budgets and policies corresponding to the 81 indicators. With this collected information, the GIR prepares a synthesis report in combination with the estimates of potential emissions. In case the implementation assessment indicates that the actual emissions surpass the targeted pathway or the progress is inadequate, the Government will identify such sector and provide policy feedback.

The implementation assessment is conducted in compliance with the transparency framework of the Paris Agreement, which we expect will contribute significantly to Korea's achievement of the NDC.

<Table 5-2> Indicators for implementation assessment (non-exhaustive)

- **Target indicator: emissions by sector (potential), emissions per unit**
  - GHG emissions: total emissions, sectoral emissions
  - Emissions per unit: per-capita emissions (tCO_2eq/person), emissions to GDP (tCO_2eq/KRW mn)
- **Implementation indicator: qualitative indicator and policy indicator (81 indicators for 9 sectors)**
  - Qualitative indicator: power generation percentage by energy source, ETS allowances, LED lamp penetration rate, deployed units of EVs
  - Policy indicator: shut-down of old coal-fired power plants, introduction of environmental electricity dispatch, cap on coal power generation capacity

1.2 Institutional framework

Laying institutional framework for climate change response

Achieving 2050 carbon neutrality requires a nationwide and cross-sectoral transformation as well as a robust institutional framework that could continuously support such transformation. The basic principles and directions of Korea's climate and energy policy are indicated in the Framework Act on Low Carbon Green Growth, but circumstances have

changed from home and abroad since the enactment of the Act in 2010. Most notably, the Paris Agreement was adopted, and since then global climate action has strengthened. Institutional frameworks should be rearranged and adapted to incorporate such changes accordingly.

Looking ahead, the Government policy should be closely aligned with the efforts for the 2050 carbon neutrality. To this end, the rearrangement of the institutional frameworks will be centered around mobilizing financial resources, i.e., climate change response fund, achieving a just transition for climate-vulnerable populations and communities, and promoting green finance.

Linking mitigation policies with energy polices

Considering that energy combustion process is the largest source of GHG emissions, mitigation and energy policies are closely connected. Korea's Framework Act on Low-carbon Green Growth sets forth basic provisions on its climate change response and energy policies, and the importance of interlinking the two policy streams.

The Act states that the Basic Plan on Climate Change Response and the Basic Energy Plan, both of which are overarching plans encompassing Korea's climate and energy policies, should be established every five years for a planned period of 20 years. The Government will focus on securing high level of coherence between the two plans to ensure climate and energy policies are aligned to create synergies.

Considering climate change impact in policymaking

A government's way and purpose of disbursing its budget shows the values and policies it is most committed to. Government budget primarily works to provide direct/indirect support for its people and industry, and additionally helps to build social infrastructure. Therefore, considering climate change impact in establishing the Government's fiscal policy and setting national priorities is the first task that should be undertaken for the transition towards a carbon-neutral society.

High-carbon projects should be restrained from the stage of designing and disbursing government budget while low-carbon projects with environmental benefits should be encouraged even if they involve higher costs.

Building foundation for energy transition

To lay the foundation for the clean energy transition, it is essential to take measures to change the current fossil fuel-oriented energy market system. The power supply system needs to transform in the way that it takes into account the costs of environmental pollution as well as the transaction costs for emissions trading so as to ensure a clean and safe energy distribution. Power pricing scheme also needs to incorporate social values of adopting decentralized and eco-friendly power sources. Furthermore, a flexible and rationalized electricity rate system that takes into account cost-changing factors, i.e., production costs, should be established to send a clear price signal to the market for better management of energy demand and enhancement of energy efficiency.

With growing use of renewables, it will be crucial to solve the problem of volatile and intermittent power supply issue. We will need a real-time operation system of the power market that meets consumers' needs and a reliable institutional framework to shift into a smart grid system, backed by robust financial supports.

1.3 Carbon pricing

Role of Emissions Trading Scheme (ETS)

Carbon pricing is the most cost-effective market mechanism that incentivizes economic actors to reduce GHG emissions. The economic signal is given by a carbon price and businesses decide for themselves which low-carbon technologies they should adopt, and they usually start by investing in technologies that are easy to apply and have the largest mitigation effect. The benchmarking-based allocation of allowances also contributes to the fair distribution of mitigation benefits across industries and to the proliferation of efficient mitigation technologies.

As the first country in Asia that adopted a nation-wide ETS, Korea has set itself as a leading nation in implementing carbon pricing policies. The Korean ETS, or K-ETS sets emissions caps in consideration of its reduction target and allows companies to freely trade their surplus allowances. The scheme has an effect of incentivizing corporate investments in low-carbon technologies. The Government will gradually scale up the auction volume in the K-ETS while increasing the share of benchmark-based allocation, both of which are essential policy instruments to achieve the Korea's 2050 carbon neutrality. The Government will also continue to enhance support for low-carbon technologies.

Taxation and charges

Carbon price literally refers to the price of carbon traded in the market, but it also includes carbon tax and subsidies for fossil fuels. The taxation on the use of fossil fuels works as a positive tool to accelerate the low-carbon fuel transition while fossil fuel subsidies have negative impacts. Effects of taxation, charges and other pricing tools should be comprehensively assessed in relation to the K-ETS to build an effective carbon pricing system. To prevent such carbon pricing scheme from harming domestic industries' competitiveness in the international market, a strong international partnership and collaboration will be required in achieving carbon neutrality.

1.4 Leadership by public sector

Public sector's leading role

The public sector is in the best position to show its commitment to and progress in GHG emissions reduction. A government's leadership in pursuing mitigation efforts could set an exemplary model and serve as a demonstration for the private sector.

Korea has operated the GHG emissions Target Management System (TMS) for the public sector since 2011. A total of 800 government entities, comprised of central and local governments and public agencies are subject to the TMS. Approximately 11% of GHG emissions has been reduced since its introduction. The Government will continue to identify and introduce various policy options to encourage the public sector to take the lead in mitigation efforts. Improving building energy efficiency, scaling up deployment of renewables and mandating the use of eco-friendly vehicles are some examples of those policy options to ultimately achieve public sector's carbon neutrality by 2050.

1.5 Korean Green New Deal

Pushing for Green New Deal as catalyst for carbon neutrality

In achieving 2050 carbon neutrality, public investments play a catalyzing role.

Last July, Korea announced its plan for the Korean New Deal as a strategy to overcome the Covid-19 pandemic as well as to address climate and ecological crises. With the aim

of investing KRW 160 trillion by 2025, the Korean New Deal includes the Green New Deal as one of its pillars. The Green New Deal also aims to mobilize KRW 73.4 trillion by 2025.

Key areas of Green New Deal

The Green New Deal is underpinned by the following three key areas.

First area is green transition in cities, spatial planning and living infrastructure. Green remodeling will be carried out in public facilities as they are closely related to the people's daily life. The public facilities will include 225,000 household units of public rental housing, 2,890 units of school building, 2,000 healthcare and medical centers and 1,000 cultural facilities. The remodeling will involve: installing renewable energy facilities; improving building insulations; and using eco-friendly construction materials. This retrofitting aims to reduce building energy consumption while increasing building energy production to turn the facilities into zero-energy buildings. Furthermore, the Government plans to create a total of 25 smart green cities that are more climate-resilient and conduct urban ecosystem restoration projects.

Second area is the proliferation of low-carbon and decentralized energy. The Government plans to increase solar and wind energy facilities by 3-fold by 2025 through green energy projects. A profit-sharing model will be further developed to ensure that the profits from the green energy projects are shared with local communities. Support for eco-friendly vehicles will reach not only passenger vehicles but also for freight trucks, construction machinery and other vehicle types. The Government also plans to make R&D investments in future mobility to be the world leader in this area. In line with this effort, the Government will contribute to the transition to green shipping through expansion of eco-friendly vessels, including replacement of public vessels with eco-friendly vessels.

Third area is building innovative green industry ecosystems. By 2025, the Government will carry out Smart Green Industrial Complex project at 10 industrial complexes for their energy independence and create Green Start-up Towns to foster the growth of small- and medium-sized enterprises specialized in green businesses. The Government also plans to mobilize KRW 1.9 trillion of green finance to support business investments in green transition.

Next steps

The first step of Korea's carbon neutrality has been already taken with the Green New Deal. However, for the Green New Deal to ultimately lead to carbon neutrality, the role of public

investment as a pump-primer is critical. In other words, the public investment should play the role of further scaling up private efforts for carbon neutrality.

After its announcement of the Korean New Deal, the Government has released strategies to promote New Deal Fund and regionally balanced New Deal in an effort to promote private sector growth and regional development at the business and local levels. The Government will lead the changes from private sector by mobilizing the participatory New Deal Fund. Through the Fund, we will encourage businesses and people's participation. With regionally balanced New Deal, the role of local governments, who are the main actors of the Green New Deal, will be further expanded.

2. Social innovation

2.1 Raising public awareness

Raising people's awareness of climate crisis

To make people take climate action in reality, there must be a wide public recognition and broad consensus on the severity of climate crisis. The society as a whole should have a clear and deep understanding of how serious climate change is and be willing to engage in collective efforts to respond to it.

However, setting a common goal and sharing identical values with members of the society of various backgrounds and perspectives is not an easy task. To make this possible, we need a participatory process of engaging all stakeholders including the Government to discuss a set of common values and perspectives that all of us could share. The Government will play a central role in this process to help its people understand the current state of climate crisis and coordinate their different interests. People should have an access to necessary information to freely exchange their opinions and take part in the Government's policymaking. We need to build a climate information platform to provide such access for the general public.

Public outreach campaign for climate action

Public campaign is a powerful tool to raise people's awareness of the climate situation and mobilize people's climate action in reality. Traditional public outreach methods include employing celebrities as climate ambassadors and using cultural contents (i.e., e-comics, animation movies, documentary films, etc.). Web-based talks, social networking services and other newly emerging channels should be also considered as options especially for the youth, because they are the next generations who will change the course of climate action in the future.

As part of its public outreach, the Government has been working on public campaigns on paperless mobile receipts, single-use items, and public transportations. The Government also designated a week around 22 April as "climate change week" to raise people's attention to the climate change issue.

[Figure 5-1] Public outreach campaigns on climate change

Poster for climate change week	Cool biz casual work attire campaign during summer	Warm biz campaign during winter
		

There are other incentive-based programs to encourage people to reduce their carbon footprints: Carbon Point Program and Green Card. The Carbon Point Program offers households monetary rewards in proportion to the amount of saved resources (i.e., electricity, water and gas). Currently 2.8 million households are participating in this program. The Green Card gives cardholders discounts for using public transportation and buying eco-friendly products. A total of 20 million Green Cards has been issued so far, encouraging people's eco-friendly purchases.

Environmental education

The role of government and industry is critical in tackling climate change, fine dust and water pollution, but the general public is also closely related to these environmental issues. For climate change, we are polluters and victims at the same time. All of us are responsible for GHG emissions, but affected by climate change impacts as well. Therefore, a fundamental solution to overcome environmental and climate crises facing us is to help citizens understand what causes climate change and what should be done to tackle it and make them stand at the forefront of our environmental issues. The solution is delivered by the environmental education.

The Government will offer various education opportunities for people's knowledge and capacity-building on climate change response. Previously economic perspectives and short-term approaches were adopted in climate change education programs, but going forward, long-term values and sustainability should be introduced more to the curriculum.

Current national-level education programs need to be diversified at local-level and expanded into school education programs to provide lifelong learning opportunities for people at all ages.

Higher education and research

Higher education at universities and colleges has a significant role to play in environmental education as primary and secondary education does. For the social and cultural paradigm shift we aspire to, R&D projects with long-term perspectives should be continuously carried out by universities, the place for cultivating talents and intellectuals. We need more graduate schools dedicated to fostering professionals with high level of expertise in climate change, offering a multidisciplinary curriculum considering the complexity of climate change issue. This will contribute to fostering more climate specialists who will meet the future needs of businesses in their climate risk management, thus creating more jobs.

The Government will expand the scope of the Green Campus project, currently undertaken at university level, to open up a participatory process for education, research and local cooperation for all stakeholders. This Whole Institution Approach will provide educational institutions with new opportunities to innovate themselves and set an exemplary model of sustainable development for local communities.

2.2 Governance and decision-making

Broader public engagement in policymaking

In the past, the whole process of designing and making policies was undertaken by governments alone, and the public opinions were sought only after the policies were implemented. Recently, however, as people's right to know gains importance and diverse web-based communications channels become available, there has been a growing public demand for the engagement in policymaking process.

In fact, the 2050 Carbon Neutral Strategy is the prime example of such public engagement in policymaking. In establishing the Strategy, public opinions were taken into consideration to the maximum extent possible. The 2050 Low-carbon Vision Forum described in Chapter I has been operated for nine months from the stage of outlining the Strategy. Then the Government built on what was discussed and produced from the Forum and incorporated the results of extensive public discussions in establishing the Strategy.

The largest group of stakeholders of the Government's climate change policy is its people. People should be fully informed and have a greater access in their engagement in policymaking. They have the right to be heard as they are the main stakeholders of national policies. Previously policymaking process was participated by specific sectors and groups of people – experts, businesses and civil society. The new policymaking process, therefore, should include the youth and elderly, who had been left unheard in the past. The youth, in particular, should be given opportunities to participate in climate policymaking because they will be the generation who will be most affected by climate change.

Enhancing conflict management mechanism

A departure from universal values shared among members of the society over a given period of time inevitably causes conflicts. An aspiration towards carbon-neutral society means a departure from fossil fuel-oriented growth, which could threaten livelihood of fossil fuel workers. In setting up the policies from which sharp conflicts of interests are anticipated, we cannot rely on conventional conflict management.

To resolve such conflicts, we should first build a broad public consensus around the issue at stake. A public deliberation process, used in Korea to resolve the fine dust issue, could be another effective solution. Building a mechanism dedicated to conflict resolution is also important. Instead of taking one-off responses whenever conflict arises, we should set up a specialized organization with the system that predicts and prevents potential conflicts in order to minimize unnecessary disputes.

While people seek to become the center of action in bringing a carbon-neutral future, they should also benefit from such action. Benefits and progresses from carbon-neutral transition should be distributed in an equal and fair manner. Especially for renewable energy projects carried out at local level, a clear profit-sharing mechanism should be established to motivate participation by local communities and minimize potential conflicts among residents.

Laying groundwork for just transition

A carbon-neutral transition will improve sustainability in industry sector in the long-term, but in the short-term it could downsize fossil fuel-based businesses and put existing jobs and livelihoods in jeopardy.

In preparation for such transition and subsequent industrial restructuring, we should ensure that the workers from conventional industries are provided with retraining opportunities

to build capacity and move to new industries. Those who will have lost jobs in the transition should be provided with support for living and job opportunities in other businesses.

The Government is fostering human resources for carbon-neutral transition by developing a national standard for vocational skills and expanding job training programs for low-carbon new industry. From January 2021, the Government plans to scale up programs to match up people with job opportunities and provide the unemployed people with unemployment insurance. Unemployment benefits, job training opportunities and job counselling will also be provided to strengthen the social safety net. Through such support, vulnerable populations to be affected by the transition will receive support for their livelihood and retraining opportunities.

2.3 Role of local governments

Greater role of local governments

It is clear that the central government alone cannot lead the entire population towards a national vision. Local governments' role is vital in broadening people's understanding of low-carbon transition and keeping momentum for it. Especially for emissions reduction in the transportation and building sector, we need strategies and implementation at local level as the tasks, such as building infrastructure for eco-friendly vehicles and improving energy efficiency in old buildings, require local actions. Central and local governments should jointly establish a cooperative model for just transition in consideration of their respective roles and find a way forward to operate it efficiently.

Local governments' action to establish their own visions could inspire the central government to bolster its climate action. In Korea, 17 metropolitan cities and 63 municipalities declared their aspiration for 2050 carbon neutrality and launched the Carbon-neutral Cities Coalition in July 2020. Such local action will prosper going forward, catalyzing carbon-neutrality transition at national level.

Emissions reduction projects at local level

In GHG emissions reduction projects, local governments are increasingly taking on a growing role as project developers. The city of Seoul has been working on "One Less Nuclear Power Plant" policy and providing financial support for small-scale solar power generation. Jeju

Island is focusing its investment in increasing energy independence under the target of becoming a Carbon-free Island in 2030. Similar community-level actions are also found. The village of Seongdaegol's "Living Lab Project" is the prime example. The Living Lab is a community-based program run by local residents' voluntary participation with the aim of addressing social issues. The program has shown the possibility of community-level low-carbon transition.

[Figure 5-2] Seongdaegol Village Living Lab Program

2.4 Green finance strategy

Green finance and climate change

Green finance is part of the sustainable finance that takes into account environmental, social and governance (ESG) considerations, focusing especially on climate change and environmental elements. Unlike traditional finance mainly focusing on profitability by striking a balance between financial return and risk in managing assets, the green finance aims to increase resilience to external shocks such as climate change and other environmental risks in forecasting financial return and risk.

The impacts of climate change will grow further, having serious repercussions on real economy and financial system. Climate risks include not only physical damages from natural disasters or air pollution, but also investment losses to be incurred by stranded assets particularly in fossil fuel industry. Climate risks could also cause financial losses for businesses and have adverse impacts on their lenders, i.e., banks and financial institutions, which could grow into system-wide risks. Managing climate risks, therefore, is gaining importance in the aspect of securing financial stability of the market. The Government plans to take a series of policy measures to promote green finance.

Mobilizing green finance

Fostering green industry is a key to the success in green transition. For the continued growth of green industry, securing reliable funding sources is essential, and there are several means of mobilizing funding sources that can be arranged by the Government. For instance, providing loan interest deduction for solar energy businesses, LED lamp projects and other green projects could be one option while selling investment funds for green industry growth could also be effective. The scale and types of such green investment funds should be expanded and diversified.

Korea will continue to expand its investment in certified green technologies and facilities for air pollution prevention and GHG emissions reduction. Continuous efforts are needed to create policy funds investing in environmental businesses and overseas environmental projects. Such policy funds could be mobilized through the combination of government funding and private investments raised for the purpose of fostering green industry growth. The investments made from such policy funds could play a role as pump-primer and contribute to further growth of environmental businesses, especially the ones that are small but has strong potential. It is also important to support those businesses to ensure they will grow into flagship companies and expand their entry into the overseas market.

The Government will communicate more closely with the private sector to unlock private finance for environment sector. Having Investor Relations events for environmental industry and regular meetings with asset management companies are part of such communication efforts. As such, the public sector will take the lead in accelerating the green transition across our society.

Establishing taxonomy for green finance

For green investments to produce real environmental benefits, the so-called “green- washing” must be prevented. Greenwashing is a process of providing investors with misleading information that a particular investment is environmentally sound. We need a taxonomy that could inform investors of whether an investment is truly environmentally- friendly to weed out greenwashing.

The EU is in the process of developing a taxonomy for sustainable finance to scale up financial flows into sustainable investments and wipe out greenwashing. Its Green Bond Standard is planned to be aligned with the taxonomy. Korea also plans to build up a taxonomy for green finance to channel financial flows into the businesses with real environmental benefits.

Better access to ESG information through TCFD

ESG stands for Environmental, Social and Corporate Governance which refers to the non-financial factors in measuring sustainability and social impact of an investment in a company. Internationally a greater scope of ESG disclosure is being encouraged to promote socially responsible investments and sustainability at corporate level.

Upon G20's request, the Financial Stability Board launched a Taskforce on Climate-related Financial Disclosures (TCFD) that recommends all companies including financial firms disclose information on climate change-related financial risks in a transparent manner. The Ministry of Environment of the Republic of Korea has declared its support for the TCFD in May 2020.

The Government is pursuing to realign the environmental information disclosure system and encouraging businesses, especially listed ones to disclose their environmental information. The Government further plans to encourage other businesses including financial institutions to disclose their financial information in accordance with the TCFD recommendations.

For individual companies to disclose such information as recommended by the TCFD, the assessment of climate- and environment-related risks to the entire industry should be conducted, but the industry currently has only limited information on such risks. The Government will build an institutional framework for climate- and environment-related risk assessment so that each industry sector and individual companies could assess their own risks and have an access to the risk information.

[Figure 5-3] TCFD recommendations

Governance	Strategy	Risk Management	Metrics and Targets
Disclose the organization's governance around climate-related risks and opportunities.	Disclose the actual and potential impacts of climate-related risks and opportunities on the organization's businesses, strategy, and financial planning where such information is material.	Disclose how the organization identifies, assesses, and manages climate-related risks.	Disclose the metrics and targets used to assess and manage relevant climate-related risks and opportunities where such informations is material.

The Government also plans to establish a guideline for environmentally responsible investments for private sector investors. The investors could use this guideline in accessing the disclosed information on corporate environmental risks and opportunities. The guideline

is expected to help investors make informed decisions and promote environmentally sound investments.

Scaling up green finance infrastructure

Setting up dedicated organizations and capacity-building facilities is critical for policies and institutional frameworks to take hold. To further promote ESG and mobilize green finance, we need a specialized agency that provides environmental information management and disclosure services and targeted education for businesses.

Fora, seminars and conferences to share knowledge on green finance are becoming increasingly important as well. A vibrant exchange of opinion should take place through discussions among various stakeholders from governments and businesses. Such extensive discussions will be the basis of paving a way forward for green finance of our society. Korea will fully engage in international discussions on climate change-related risks and green finance and use the lessons learned to improve our policies. We will continue to closely work with the TCFD and UNEP Finance Initiative as well.

3. Technological innovation

3.1 Establishing policies for technological convergence

Driving R&D for technological integration and convergence

GHG emissions reduction requires a system-wide approach across the national climate and energy policies, and a stand-alone technology will never be sufficient undertake the task. This is the reason why we need a significant level of R&D effort for mitigation technology convergence.

The prime example is Power-to-Gas (P2G) and Power-to-Liquid (P2L)[63] technologies. The P2G and P2L are core technologies to store extra power from renewables and convert it into other forms of energy. These innovative technologies could be developed through the combination of renewable energy-based power generation and chemical conversion technologies. Large-scale hydrogen production is a prerequisite for our vision of hydrogen-based economy. Europe and Japan already have a hydrogen production technology using natural gas reforming, available for commercial use. This technology has advantages of reliable hydrogen supply and cost competitiveness, but also has a limitation of generating CO_2. To overcome this limitation, R&D efforts need to be pursued to integrate the current technology with CCUS for a CO_2-free, eco-friendly hydrogen production technology.

To create maximized synergies, the Life Cycle Assessment approach should be adopted in developing core mitigation technologies and a government-wide collaboration among different ministries and agencies is critical. The prime example is the ongoing CCUS technology development project led by the Government[64]. We will continue to work together at government level to make progress in such R&D projects.

To expand commercial development of basic and original technologies, it is also important to take into account users' opinions from the initiation stage of technology development. In demonstration stage, an open environment should be created to invite more companies that will actually use those technologies to engage in the R&D process.

63) The P2L technology converts renewable energy into chemical energy (i.e., hydrogen, natural gas and liquid fuel), not into electricity.

64) The project is participated by Ministry of Science and ICT, Ministry of Trade, Industry and Energy, Ministry of Oceans and Fisheries and Ministry of Environment.

Establishing R&D foundation for mitigation technologies

We need a clear set of national strategies for climate technology R&D in consideration of technological developments from home and abroad under the new climate regime. The Government will closely examine domestic and oversea R&D trends and lay the legislative framework for setting national strategies.

Looking ahead, with growing technology convergence, new climate-related business models will emerge and accordingly, the demand for international standardization will increase. Preemptive measures should be taken to be ready for such surge in standardization demand.

3.2 Evaluating mitigation potentials

Evaluating mitigation potentials from technology development stage

To secure effective mitigation tools, each mitigation technology needs to be assessed for their potentials in reducing emissions. The assessment will be conducted after comprehensively considering Korea's mitigation circumstances. The Government will find and determine where and how the data from the assessment could be used.

Before starting R&D process of all mitigation technologies, their mitigation potentials should be estimated in advance and considered from the design stage. Once those technologies are developed as part of an emissions reduction project, more accurate and systematic assessment should be conducted for their mitigation potentials. At this stage, the technology development should be aligned with the general project purpose and the assessment data should be used as the basis for policymaking.

We also need consistent methodologies and standards for measuring mitigation potentials. The measured data will be also used as the basis in deciding which technologies are eligible for government R&D funding as well as new project planning and evaluation.

An observation-based GHG emissions verification system should be established, using artificial satellites. The emissions reductions made by mitigation technologies should be verified through this system to objectively assess their technological effects.

Assessing co-benefits of adaptation for carbon-neutral society

Adaptation techniques, i.e., building green infrastructure and urban ecosystems are critical as they create carbon sinks which produce co-benefits of reducing further GHG emissions.

A system of assessing the effects of adaptation techniques will help lay out an optimal trajectory towards a carbon-neutral society creating synergies with mitigation technologies.

Adopting Life Cycle Assessment approach in technology assessment

Besides mitigation potentials, there are other environmental impacts that need to be assessed in developing sustainable, low-carbon green technologies. Certain technologies could contribute to GHG emissions reduction, but at the same time they could have adverse environmental impacts such as resource depletion, acidification and chemical poisoning. Due to the possibility of such trade-offs, a comprehensive assessment of overall environmental impacts needs to be conducted in developing low-carbon technologies.

As technologies are increasingly combined and integrated, synergies from technological convergence should be examined as well. Environmental impact assessments of applying a specific line of technologies should be conducted both at national and global level. For instance, the EV deployment in automotive industry could have a significant environmental impact not only in transportation but also in power generation sector. As environmental impacts could vary widely between sectors, a comprehensive assessment is needed to precisely understand how the applied technology affects each industry.

For the environmental impact assessment of the technologies applied in various sectors, we could adopt the Life Cycle Assessment (LCA) approach for quantitative evaluation. We also need a common LCA model to assess overall environmental impacts of the technologies at R&D stage so that it could be used in developing R&D strategies as well as in policymaking for promoting technologies.

3.3 Scaling up investment in technological breakthroughs

Transitioning to a carbon-neutral society would be impossible if we depend on existing mitigation technologies that are commercially available. Current R&D is mainly focused on developing technologies for commercial use and deploying them on the market. To lead the future market with our technological competence, however, we need greater efforts to keep pushing the boundaries and trying out new technological breakthroughs. R&D for basic and original technologies should continue to evolve to create such technological innovations.

In the present R&D circumstances in Korea, compared to the investment in technologies readily available for commercial use, much lower investment is being made in creative basic and original technologies. To achieve carbon neutrality, our society needs to improve readiness for the future energy mix and develop original technologies that will enable us to dramatically reduce GHG emissions. Further actions are needed to accelerate technological innovations and breakthroughs that will allow us to fully harness their potential in the future[65].

Mitigation technologies currently available for commercial use are reaching their limits in terms of energy efficiency and capacity, raising pressing needs for new innovative technologies[66]. R&D for key innovative technologies – smart grid, ESS, smart heating, ventilation and air-conditioning, and prognostics and health management – should be continuously pursued to improve overall energy efficiency and convert into low-carbon industrial processes that will enable us to cut more GHG emissions from the energy sector.

A hydrogen-based economy could be achieved by adopting highly efficient, reliable, affordable and innovative technologies in all processes of producing, storing, distributing and using hydrogen. Latest technological breakthroughs, such as artificial photosynthesis and petrovskite solar cells, are expected to create a high value-added technological leap-forward and should be developed further as well. The Government will establish a roadmap that lays out various R&D strategies and plans for such technological breakthroughs and pursue efforts to scale up investment in them.

65) In the past lead acid batteries were most widely used type of battery, but lithium-ion batteries started to dominate the market in 1991 with its development by Sony. Recently as safety concerns arise in relation to battery explosion risks, R&D is expanding on solid-state batteries.

66) For instance, maximum efficiency of amorphous solar cells is approximately 30%, so new type of solar cells using advanced device or new materials (i.e., petrovskite or tandem solar cells) need to be developed to overcome this limitation.

Chapter 6

Way Forward

Establishing the implementation framework for the Strategy

The 2050 carbon neutrality has become a global common goal to address climate change and a new international economic order. Korea should also join this paradigm shift and move from “adaptive GHG emissions reduction” towards “proactive climate response” in building a new economic and social structure fit for a carbon-neutral society in 2050.

For the robust implementation of the Strategy, the Government announced the “2050 Carbon Neutral Strategy Action Plan” on 7 December 2020. At this critical juncture of great economic and social transformation, the Plan outlines the essential elements for achieving carbon neutrality, economic prosperity, and a better quality of life, all at the same time.

The Plan lays out three important policy directions: low-carbon economic structure, low-carbon industrial ecosystem, and just transition towards carbon-neutral society, along with 10 key tasks such as energy carbon neutrality, industry transformation and circular economy roadmap.

Implementation of 2050 carbon neutrality

The 2050 carbon neutrality is a long-term mission that spans around 30 years, hence it must be backed up by a robust implementation mechanism and clear strategies for consistent implementation.

The Government will build a strong governance structure, including by establishing the Presidential Committee on 2050 Carbon Neutrality for the systematic implementation of carbon neutrality by 2050. All relevant policies will be presented to the Committee for further consideration.

We will develop scenarios for the 2050 carbon neutrality, taking into account Korea’s mitigation potential, and level of technological advancements. Based on such scenarios, we will also establish implementation strategies and specific plans by sector.

Along the process, we will take a closer look into the way forward towards the 2050 carbon neutrality and reach social consensus on the path we should tread upon. We will do our utmost to further raise our ambition level of the 2030 emissions reduction target in our NDC before 2025.

Looking ahead, technologies to tackle climate change will evolve with continued advances in innovation and technological breakthroughs, and the pace of such advances will accelerate. Global climate action for carbon neutrality will also gain traction going forward and the action will become even stronger and more concrete.

In line with such global progress, this stake in Strategy will be reviewed and updated on a regular basis so that we may take a step closer towards better, carbon-neutral future.

2050 Carbon Neutral Strategy of the Republic of Korea

towards a sustainable and green society

2050 CARBON NEUTRAL STRATEGY

OF THE REPUBLIC OF KOREA

TOWARDS A SUSTAINABLE
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The Government of
the Republic of Korea