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Fourth National Communication of the Republic of Korea

under the United Nations Framework Convention on Climate Change

November 2019

The Government of
the Republic of Korea

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Foreword

I am very pleased to submit the 4th National Communication of the Republic of Korea (ROK), which contains our efforts and achievements in mitigating climate change.

Climate change is the most serious threat facing humankind and a problem that we must work together to solve. According to the World Meteorological Organization, the four-year period from 2015 to 2018 was the hottest since meteorological record keeping began. In particular, their findings show that the average global temperature was 1°C higher in 2018 than before industrialization. To cope with the looming crisis of climate change, the international community adopted the Paris Agreement in December 2015, which went into force in November of 2016. Under this agreement, all signatory countries agree to work to reduce greenhouse gas (GHG) emissions. The Parliament of the ROK has ratified the Paris Agreement, depositing its instrument of ratification with the United Nations Secretariat in November 2016.

All Parties under the United Nations Framework Convention on Climate Change (UNFCCC) are required to submit National Communications that contain GHG reduction policies and future plans in order for the UNFCCC to review their national GHG reduction efforts. The purpose of National Communications is that all Parties share their efforts and achievements in responding to climate change so that they may better work hand-in-hand to solve the issue. The 4th National Communication of the ROK reflects our efforts and achievements in mitigating climate change, including national circumstances, national greenhouse gas inventory, mitigation policies and actions, financial assistance, technology development and transfer, and capacity building.

The ROK has established legal and institutional instruments to fight climate change, including the legislation of the "win-win relations between environment and economy" paradigm through the Framework Act on Low Carbon, Green Growth and the introduction of an Emissions Trading System. The ROK has set its 2030 target of reducing greenhouse gas emissions by 37% from business-as-usual (BAU) levels in line with the adoption of the Paris Agreement in 2015, and finalized and implemented a roadmap to achieve the target in July of last year.

The ROK will continue to make proactive efforts to cope with climate change. To embrace the move toward eco-friendly, low-carbon energy sources, the ROK will boost the share of renewables in its energy mix to 20 percent by 2030 while scaling back coal-fired power plants. In addition, each sector of economy will work together with industry to propose a specific measure that will reduce GHGs. Furthermore, the government will provide various investment incentives to help achieve GHG reduction targets without disruption.

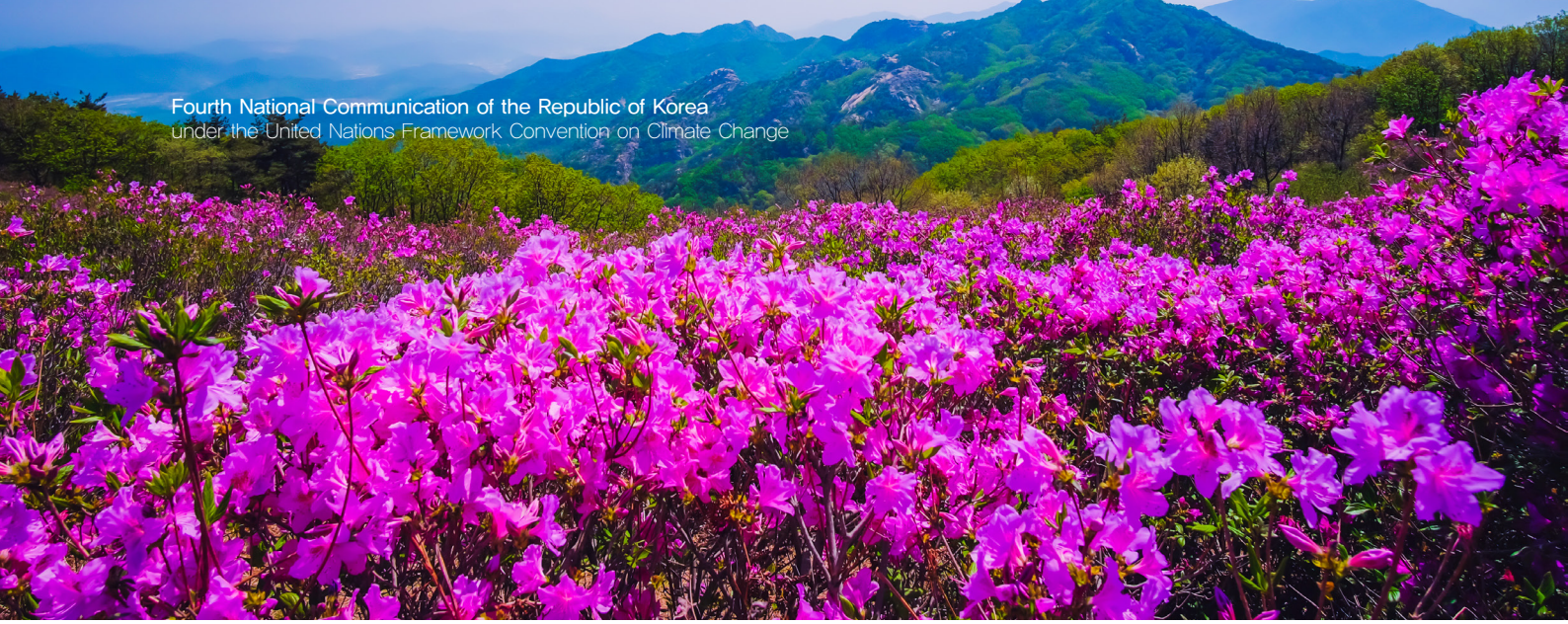
Also, the ROK will continue to strengthen its support for and cooperation with developing countries in jointly responding to climate change, as President Moon Jae-in revealed in his October 2018 keynote speech at the P4G, Partnering for Green Growth and the Global Goals 2030.

Global solidarity in the implementation of measures to deal with climate change must be further strengthened. I hope this 4th National Communication of the ROK serves as an opportunity to respond to climate change and strengthen cooperation with the international community.

Thank you.

November 2019

Cho Myung-rae, Minister of Environment



Royal azaleas of Hwangmaesan Mountain, Hapcheon-gun, Gyeongsangnam-do

Executive Summary

1. National Circumstances

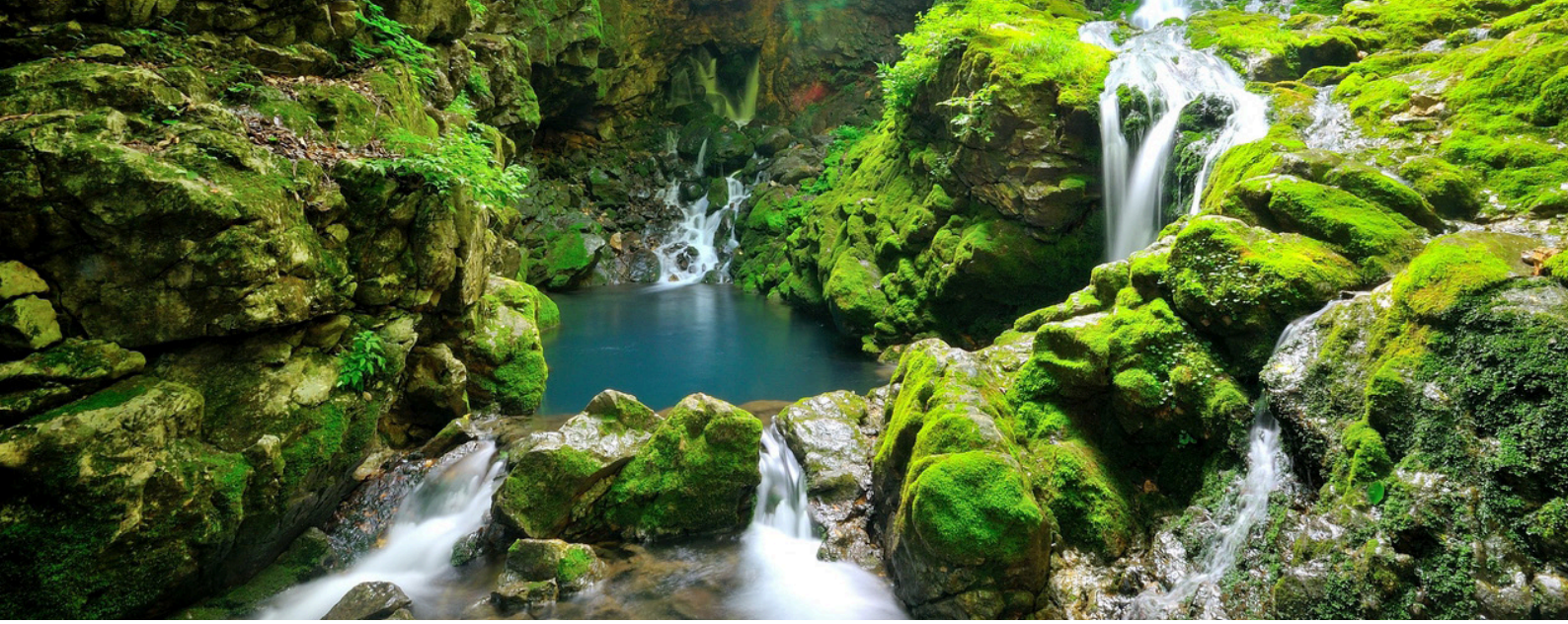
The Republic of Korea (ROK) is a mountainous country with four distinct seasons, and has a total population of 51,607,000 (2018). Exports and the manufacturing sector play a significant role in the national economy, and as of 2017, dependence on exports stood at 37.5%, while the share of the manufacturing sector accounted for 30.4% of the nominal GDP in 2017.

Even under the socio-economic structure of continuous population growth and high manufacturing and export share, the ROK has been taking active measures, such as ratifying the Paris Agreement in November 2016, to shift to a low-carbon economic structure and move forward with international community's endeavors to respond to climate change.

2. National Greenhouse Gas Inventory

The ROK prepared the national GHG inventory from 1990 to 2016 using the IPCC (Intergovernmental Panel on Climate Change) Guidelines for Energy, Industrial Processes, Agriculture, and LULUCF (Land Use, Land-Use Change and Forestry), and Waste sectors. The national GHG inventory includes carbon dioxide (CO_2), methane (CH_4), nitrous oxide(N_2O), hydrochlorofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) defined in the Kyoto Protocol, and they are expressed by CO_2 equivalent (CO_2eq.) using the Global Warming Potentials (GWPs) in the Intergovernmental Panel on Climate Change (IPCC) Second Assessment Report (SAR).

In 2016, the national GHG emissions were 694.1 million tons CO_2eq. and net emissions including sinks were 649.6 million tons CO_2eq. Total emissions in 2016 were 0.2% higher than in 2015 because of increased emissions from road transport (4.4 million tons, by 4.9%), residential (1.8 million tons, by 6.0%), chemicals (1.4 million tons, by 3.8%), and petroleum refining (1.3 million tons, by 8.1%) sectors. It was analyzed that the increased emissions in road transport were due to increased fuel consumption caused by the increase in the number of registered vehicles (by 3.9%).



Moss Valley in Samcheok-si, Gangwon-do
Photographs: Korea Tourism Organization (Jeong Gyeong-hee)

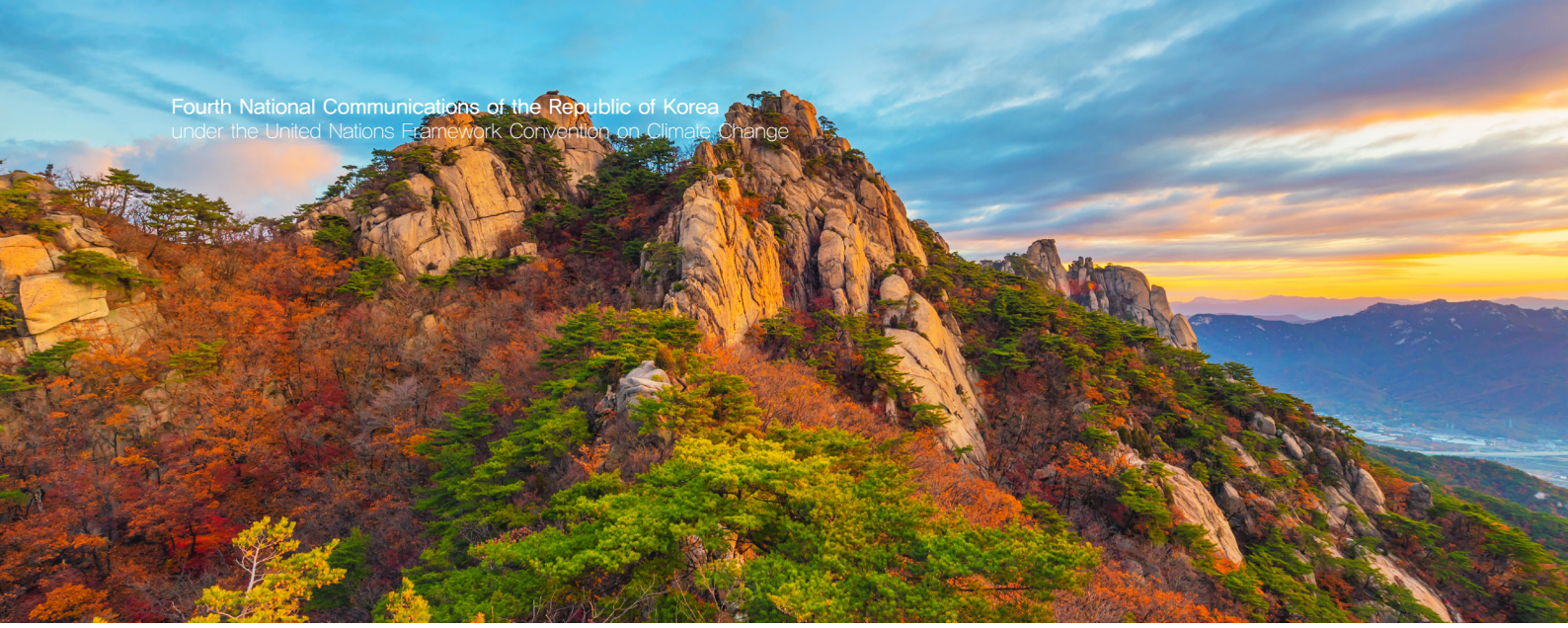
3. Mitigation Policies and Actions

In May 2015, the ROK set a new national GHG reduction target of 37% below business-as-usual (BAU) level by 2030. The ROK prepared the Roadmap to Achieve the National GHG Reduction Target for 2030 in September 2017, which provides basic directions for achieving the national GHG reduction target. This roadmap specifies the emissions projection, reduction target, and major reduction plans by sector and sub-sector for 2030. According to the roadmap, the ROK will reduce GHG emissions by implementing technologies and policies taking into consideration sector-specific circumstances for energy transformation, industry, buildings, transportation, waste, public/other, and agriculture and livestock sectors.

In 2014, the ROK prepared GHG emission projections for 2030, using the latest data from the 2nd Energy Master Plan. Considering these conditions, total energy demand is projected to grow at an average annual rate of 1.5%, and GHG emission is expected to increase at an annual average of 1.33%.

The ROK introduced its Emissions Trading System (ETS) in 2015 to manage GHG emissions using the market mechanism. The ETS operates under three-year plans for Phase 1 (2015-2017) and Phase 2 (2018-2020), and five-year plans will begin from Phase 3. There are 23 business entities regulated under Phase 1, and the pre-allocation is 1,642.9 million tons CO_2eq., accounting for 92% of the total 1,777.1 million tons CO_2eq. of permissible emission volume. The ROK also operates the GHG and Energy Target Management System (TMS) to manage small and medium or less-sized business entities in terms of emissions, which are not covered by the ETS.

The ROK established a separate basic plan for each sector in setting mid- and long-term targets and directions and is making efforts to reduce GHG emissions by implementing detailed policies and measures. Along with these, the ROK is promoting policies to increase the share of new and renewable energy through the Renewable Portfolio Standard (RPS) in the power generation sector, strengthening energy demand management and expanding the supply of high-efficiency equipment in the industrial and buildings sectors, and popularizing eco-friendly vehicles and improving the transportation logistics system in the transportation sector.



Dobongsan Mountain, Dobong-gu, Seoul

4. Climate Change Impacts and Adaptation Measures

The impact of climate change in the ROK is evident in a wide range of aspects including weather, ecology, environment, and water resources, which occur regionally in different patterns. Therefore, to prepare for and cope with large-scale natural disasters caused by climate change, it is important to use systematic and scientific climate forecast information.

The result of climate change projections indicate that the average temperature and precipitation in the ROK will rise by 2.9℃ and by 38.8mm, respectively, in the second half of this century (2071-2100). In addition, climate change is expected to accelerate the start of spring and summer seasons and reduce autumn and winter seasons. As a result, it is expected that the days of heat waves and summer will increase to 8.7 and 38.7 days, respectively, and the days of cold waves and freezing will decrease to 16.2 days and 21 days, respectively.

To minimize the damage caused by climate change, the ROK established the National Climate Change Adaptation Measures in 2010 and the 2nd National Climate Change Adaptation Measures in 2015 and is taking concrete national adaptation measures. Central and local governments and public institutions also predict risk factors and establish adaptation measures through the assessment of climate change vulnerability and risk.

Ssanggyeru Pavilion of Baegyangsa Temple in Jangseon-gun, Jeollanam-do
Photographs: Korea Tourism Organization (Yeo Jin-mo)

5. Research and Systematic Observation

To achieve the GHG reduction target, the ROK is making efforts to continuously research and develop green technologies to minimize GHG and pollutant emissions and climate technologies to cope with climate change. As part of those efforts, the ROK determined the top 10 green and climate technologies—solar cells, fuel cells, biofuels, secondary cells, power IT, CCS, byproduct gas conversion, CO_2 conversion, CO_2 mineralization, and common platforms, by the Roadmap for Securing Climate Change Response Technology in 2016 and is committed to achieving science and technology-based greenhouse gas reduction and creating new climate markets.

In the field of climate observation and monitoring, grid-based observations by satellites and radar are collected along with observations by the Korea Meteorological Administration in and around the air, marine, agriculture, and forestry sectors.

6. International Support and Awareness of Climate Change

In spite of restrictions such as the global financial crisis and rising financial deficit, the ROK announced a contribution of USD 100 million to the Green Climate Fund (GCF) at the UN Climate Summit in September 2014. Moreover, at the COP 22 in November 2016, the ROK with the European Union (EU) and seven developed countries pledged a joint statement for a financial contribution of USD 23 million for the Climate Technology Center and Network (CTCN), an unprecedented feat for non-Annex I countries.

Government organizations, including the Greenhouse Gas Inventory and Research Center of Korea (GIR), the Korea Forest Service, and the Ministry of Environment, operate their own capacity-building programs to foster experts in the fields of greenhouse gas inventory, reduction of emissions from deforestation and forest degradation, and adaptation in developing countries.

Also, the regular curricula of elementary, middle, and high schools reflect relevant contents such as the Climate Change Convention and energy saving to implement systematic environment and energy education. Along with this, the government is building climate policy partnerships with industries and private organizations to raise awareness of the seriousness of global warming and form a nationwide consensus to increase the effectiveness of climate change measures.

[Clepsydra] A water clock equipped with automatic time signal device

CHAPTER 1

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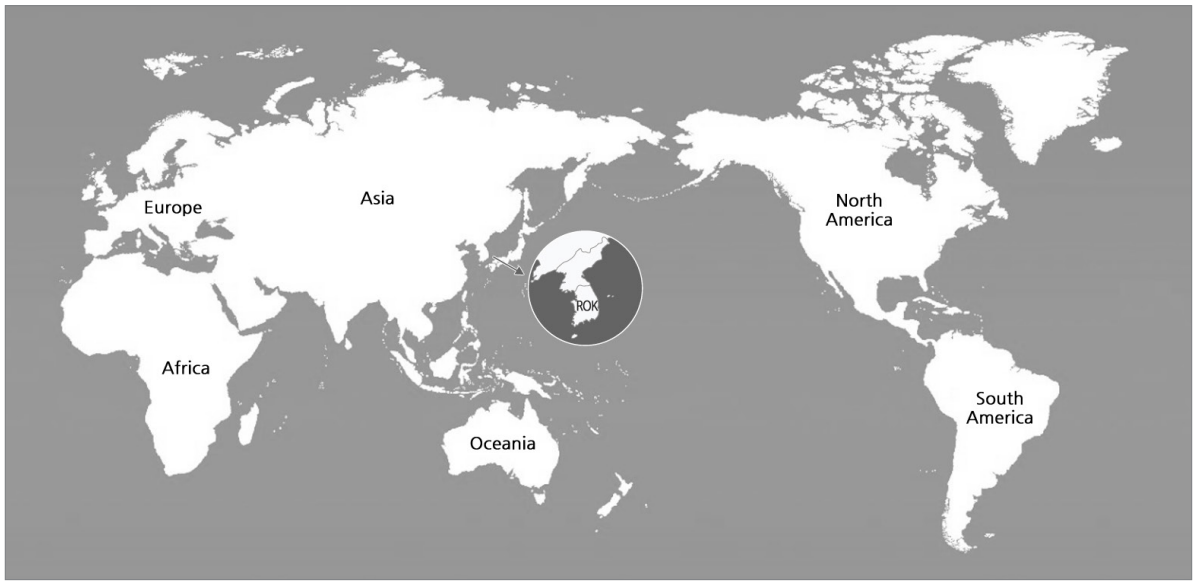
National Circumstances

1. Geography
2. Climate
3. Population
4. Economy
5. Institutional and Legal Framework

1. Geography

In terms of geographic location, the ROK shares the Yellow Sea with the People's Republic of China to the west, and the East Sea and Korean Straits with Japan to the east and south, respectively.

[Figure 1-1] Geographic Location



The ROK's topography features a general slope to the Yellow Sea from the mountain ranges in the east of the country. The degree of slope gradually decreases approaching the Yellow Sea while the slope to the East Sea is steep, leading to the development and distribution of mountain and plain areas and the distinct flow of rivers. The ROK's land area is 100,364㎢, covering 45% of the entire Korean peninsula. The average altitude above sea level is 482m and the highlands above 1,000m are mostly located in the northern region of the peninsula, whereas the southern region consists of mountains of 500m or less.

Mountain areas exceed river basins because most of the land is mountainous. The river flows are extremely irregular, and, thus more than 60% of the annual precipitation is discharged as floods due to heavy rains in summer, and due to these strong river flows, large amounts of sand and gravel are transported from mountains to downstream areas or estuaries.

The ROK's plain areas are separated by mountain ranges in the directions of Liaodong and China and located on the west and south coasts, most of which are developed downstream of large rivers. Dividing the ROK's total land area of 100,364㎢ according to usage reveals forest lands cover 63,834㎢ (63.6%), paddy fields 11,282㎢ (11.2%), dry fields 7,611㎢ (7.6%), and roads 3,251㎢ (3.2%)

2. Climate

The ROK is located in the four-season mid-latitude temperate climate zone where winters are cold and dry due to the continental high atmospheric pressure, and summers are generally hot and humid because of the North Pacific anticyclone. During spring and autumn, the migratory anticyclones often provide relatively clear skies and dry conditions. Over the 29 years (1990-2018), the annual mean temperature of the ROK is 12.8℃; the hottest month is August with a mean temperature of 25.3℃, and the coldest month is January with a mean temperature of −0.8℃.

〈Table 1-1〉 Monthly Mean Temperature and Precipitation (1990-2018)

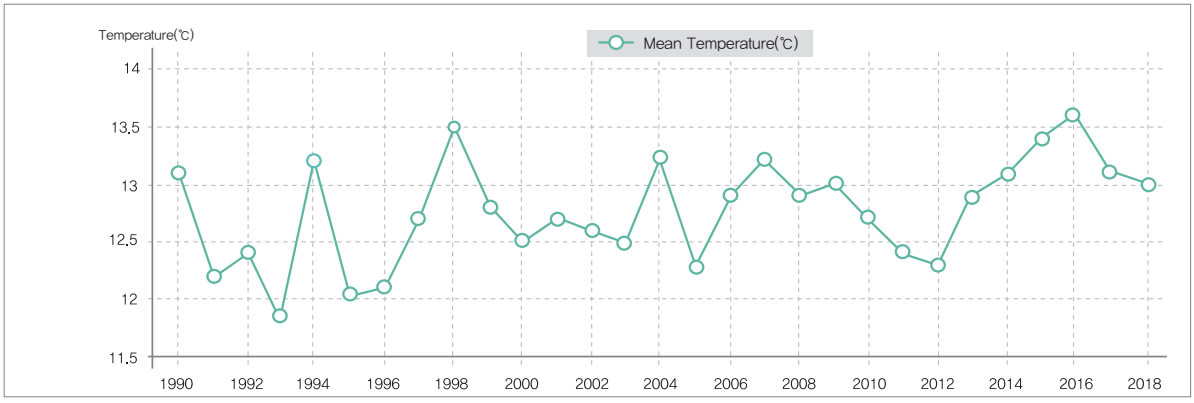
Temp. and Prec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean Temperature (℃)	−0.8	1.5	6.3	12.3	17.4	21.5	24.9	25.3	20.7	14.5	8.0	1.5
Highest Temperature (℃)	4.5	7.1	12.3	18.7	23.5	26.8	29.2	29.9	26.1	20.9	13.8	6.8
Lowest Temperature (℃)	−5.4	−3.5	0.8	6.3	11.8	17.1	21.5	21.78	16.4	9.3	2.9	−3.2
Precipitation (mm)	25.4	36.9	57.5	90.0	101.1	149.8	285.5	274.0	153.0	59.5	48.6	28.4

※ Source: Annual Weather Report (Korea Meteorological Administration)

Also, the Northwesterly wind in winter and southwesterly wind in summer are strong, and the ROK has not only seasonally distinctive wind systems but also distinct sea breeze effects along coastal areas. Humidity ranges from 60% to 75% throughout the country; 70-85% in July and August and 50-70% in March and April. About 26 typhoons occur per year in the northwest Pacific and move northward from May to October, with 90% affecting the Korean Peninsula from July to September.

The ROK is a mostly mountainous country with four distinct seasons. In the ROK, the solar radiation in spring and summer is 20% and 25% higher than the annual average, respectively, whereas in autumn and winter, 12% and 33% lower than the average, respectively.[1] When measuring wind power efficiency, 25% of onshore wind and 40% of offshore wind can be used for power generation.

[Figure 1-2] Annual Average Temperature (1990-2018)



1 2016 New and Renewable Energy White Paper (Ministry of Trade, Industry and Energy, 2016)

3. Population

As of 2018, the ROK's population was approximately 51,607,000. This is about 0.7% of the world's population and is the 27th largest country in terms of population. The ROK's population density is about 515 people/km^2, ranking behind only Bangladesh and Taiwan, excluding city-states and small countries.

The average annual population growth rate in the ROK was about 3% in the 1960s. However, as measures to suppress population growth were implemented, the rate gradually decreased and dropped sharply to less than 0.5% in 2005. Given these trends, the ROK's population is expected to reach 51,781,000 in 2020 and 51,927,000 in 2030.

In terms of age characteristics, the median age increased from 31.8 in 2000 to 42.6 in 2018 and life expectancy increased from 75.6 years (71.7 years for male and 79.2 for female) in 1999 to 80.6 years (77.0 years for male and 83.8 for female) in 2009. The proportion of the population aged 65 years and over also rose from 7.2% in 2000 to 11.0% in 2010. As such, population aging in ROK society is proceeding at a very rapid pace.

4. Economy

The ROK's economic growth rate remained high at more than 7% before the foreign currency crisis in 1998, but decreased to 4% from the 2000s. Since 2008, the ROK's growth rate has fallen to around 3% due to the global economic recession caused by the global financial crisis and European financial crisis. As of 2017, the ROK's real GDP was approximately KRW 1.556 quadrillion. In terms of GDP per capita, it is equivalent to KRW 30.25 million.

〈Table 1-2〉 Gross Domestic Product and Economic Growth Rate

Descriptions	1970	1980	1990	2000	2005	2010	2015	2016	2017
GDP (Nominal, KRW 1 billion)	2,795	39,471	197,712	635,185	919,797	1,265,308	1,564,124	1,641,786	1,730,399
Economic Growth Rate (Real, %)	10.0	-1.7	9.8	8.9	3.9	6.5	2.8	2.9	3.1

※ Source: National Income (Bank of Korea)

The ROK has promoted export-led economic growth since its initial development, and as a result, both exports, with their need for raw materials and capital goods, and imports, have expanded rapidly. In addition, Factor Income from the Rest of the World expanded at a rate similar to that of imports and exports—approximately 4%. As a result, the ROK's imports and exports to Gross National Income (GNI) ratio increased from 53.6% in 1990 to 84.0% in 2017. These figures confirm that the ROK's proportion of import and export is relatively high compared with other countries.

〈Table 1-3〉 Ratio of Imports and Exports to Factor Income from the Rest of the World and GNI

Descriptions	1970	1980	1990	2000	2005	2010	2015	2016	2017
Exports (Trillion KRW)	0.3	11.2	50.1	222.4	338.6	625.3	709.1	694.2	745.6
Imports (Trillion KRW)	0.6	14.7	51.2	209.2	316.2	585.0	600.2	581.7	652.2

※ Source: National Account (Bank of Korea)

While the economy's dependence on exports and share of the manufacturing sector recently decreased after having continuously increased from 1990 to 2011, they still play a significant role in the national economy. As of 2017, the ROK's dependence on exports stood at 37.5% and the share of the manufacturing sector accounted for 30.4% of the GDP.

〈Table 1-4〉 Dependence on Exports and Share of Manufacturing Sector in the National Economy

Descriptions	1990	2000	2010	2011	2012	2013	2014	2015	2016	2017
Export Dependence (%)	23.3	30.7	42.6	46.2	44.8	42.9	40.6	38.1	35.0	37.5
Share of Manufacturing (%)	27.3	29.0	30.7	31.4	31.0	31.0	30.2	29.8	29.5	30.4

※ Source: Korean Statistical Information Service (KOSIS), Bank of Korea's Economic Statistics System websites (ECOS)

5. Institutional and Legal Frameworks

To improve the quality of life of the people and fulfill the responsibility to the international community by realizing a low carbon society, the ROK decided in a cabinet meeting and announced the national mid-term reduction target, which includes a "reduction of 30% of GHG emissions projections by 2020," to the international community in November 2009 and enacted the Framework Act on Low Carbon, Green Growth in 2010 to build the legal basis for coping with climate change.

Also, to reach the national GHG reduction target, the ROK introduced the GHG and Energy Target Management System (TMS) for companies that emit and consume high levels of GHG and energy in 2010 and established a legal basis by enacting the Act on the Allocation and Trading of Greenhouse-Gas Emission Permits and its Enforcement Decree in 2012. It introduced an emissions trading system for 525 companies in earnest for the Phase I (2015-2017) in 2015.

In 2008, Korea introduced the National Strategy for Green Growth, the Climate Change Response Master Plan, and the National Climate Change Adaptation General Plan to pursue systematic response and measures for climate change in the mid- to long-term. The National Strategy for Green Growth is a long-term strategy for 2009-2050, which sets forth the policy goals, strategies, and directions for low-carbon green growth, including matters related to the response to climate change, energy, and sustainable development policies.

The ROK submitted the Intended Nationally Determined Contributions (INDCs) in June 2015, before the conclusion of the Paris Agreement, and legislated the reduction target for 2030 by amending the Enforcement Decree of the Framework Act on Low Carbon, Green Growth in May 2016. Measures are being taken by the ROK for its effective implementation.

In order to actively participate in global efforts to cope with climate change, the Climate Change Response Master Plan is established and implemented every five years in accordance with the basic principles of climate change response to achieve GHG reduction targets using regulations, markets, and technology and minimize the impact of climate change.

The National Climate Change Adaptation General Plan is a basic nationwide plan that presents the vision and direction of national adaptation policies as a long-term strategy for 2009-2030. For a short-term plan, the relevant ministries jointly established and implemented the First National Climate Change Adaptation Measures (2010) and the Second National Climate Change Adaptation Measures (2015). The ROK is currently implementing a mid- to long-term plan to minimize the damage caused by climate change, take advantage of climate change adaptation as a new opportunity, and turn it into a new growth engine through short-term periods (2009-2012) focused on priority projects such as vulnerability assessment and foundation building.

Moreover, in June 2015, to actively participate in the international community's efforts to respond to climate change under the Paris Agreement, the ROK submitted an Intended Nationally Determined Contributions (INDCs) that includes the GHG reduction target of 37% below BAU level by 2030 before the conclusion of the Agreement and legislated the reduction target for 2030 by amending the Enforcement Decree of the Framework Act on Low Carbon, Green Growth in May 2016. The ROK is continuing its efforts to achieve the reduction target by effective implementation measures and is pursuing basic research to submit to the international community the Nation's 2050 Long-term Low-carbon Development Strategy in compliance with the Paris Agreement for 2020.

[Celestial Globe] An astronomical device to observe and measure the orbital movements of celestial objects

CHAPTER 2

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National Greenhouse Gas Inventory

1. National Greenhouse Gas Inventory System
2. Measurement Scope and Method
3. Greenhouse Gas Emissions and Trends

1. National Greenhouse Gas Inventory System

1.1 Organizational System

The Greenhouse Gas Inventory and Research Center (GIR) is in charge of tasks related to the national GHG inventory.[2] With respect of the national GHG inventory, the GIR is in charge of (1) establishing the Regulations on the Management of the National GHG Inventory; (2) providing Guidelines for Measurement, Reporting, and Verification (MRV Guidelines) for the calculation of the national GHG inventory; (3) reviewing the national GHG inventory data as well as emission and removal factors; (4) organizing and managing the National GHG Inventory Management Committee (Management Committee), the National GHG Working Group (Working Group), and National GHG Technical Group (Technical Group); (5) collecting and preparing the national GHG inventory; and (6) developing and operating the IT system for data management.

The sectoral responsible ministries of the five sectors subject to GHG inventory[3] measurement oversee the management of the GHG inventory. A responsible ministry designates an agency with expertise in the inventory of a relevant sector (measurement agency[4]) to calculate the GHG inventory of that sector and perform tasks including the development of country-specific emission and removal factors, and reviews the draft inventory compiled by the measurement agency and submits the results to GIR. Meanwhile, a change in the organizational structure in the 2nd Biennial Update Report for 2017 is that the calculation agency for the settlement and other land categories in the LULUCF sector has been changed from the Korea Research Institute for Human Settlements to the L&H Land Housing Research Institute.

The Technical Group, as a technical advisor in relation to the measurement, reporting, and verification (MRV) of the national GHG inventory and country-specific emission and removal factors, consists of external experts from academia and research institutes. The Working Group has been established to facilitate discussions among relevant organizations with respect to the MRV of the national GHG inventory, the development and verification of emission and removal factors, and the provision and revision of relevant guidelines. The Working Group, chaired by the president of GIR, consists of director-level government officials from responsible sectoral ministries and relevant organizations such as Statistics Korea (KOSTAT), the Korea Forest Service (KFS), etc.

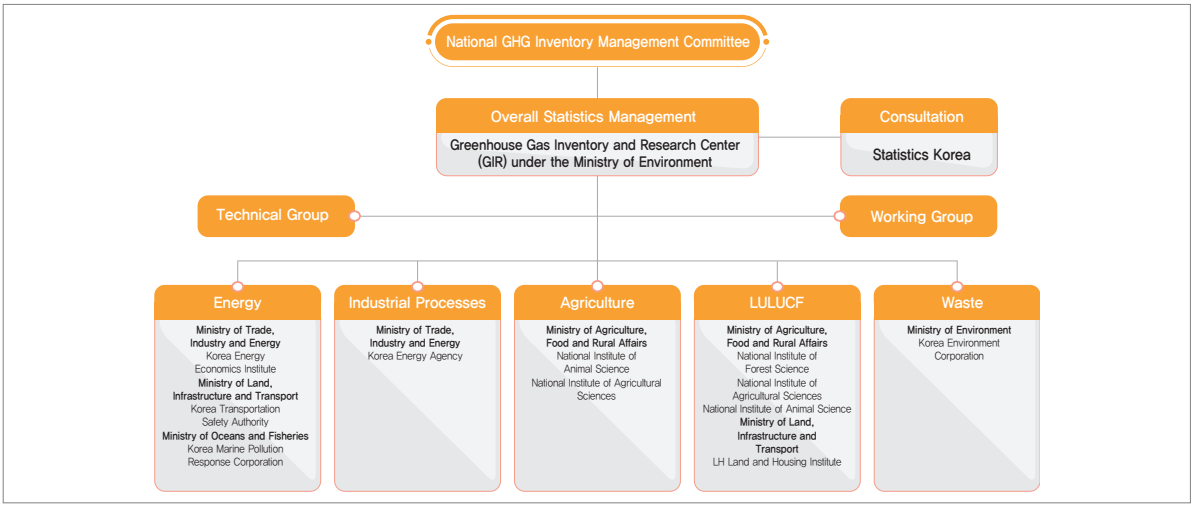
2 Article 45 of the Framework Act on Low Carbon, Green Growth and Article 36 of the Enforcement Decree of the Act

3 The sectoral responsible ministries are (1) Energy: Ministry of Trade, Industry and Energy (fuel combustion (power generation, industry) and fugitive emissions), Ministry of Land, Infrastructure and Transport (transportation (aviation, roads, and railways) and buildings), and Ministry of Oceans and Fisheries (fisheries, shipping, and ports); (2) Industrial processes: Ministry of Trade, Industry and Energy; (3) Agriculture: Ministry of Agriculture, Food and Rural Affairs; (4) LULUCF: Ministry of Agriculture, Food and Rural Affairs (forest land, wetland, grassland, and farmland); and (5) Waste: Ministry of Environment

4 (1) Energy: Korea Energy Economics Institute, Korea Transportation Safety Authority, and Korea Marine Pollution Response Corporation, (2) Industrial processes: Korea Energy Agency; (3) Agriculture: National Institute of Animal Science and National Institute of Agricultural Sciences, (4) LULUCF: National Institute of Forest Science, National Institute of Agricultural Sciences, National Institute of Animal Science, and LH Land and Housing Institute, (5) Waste: Korea Environment Corporation

The Management Committee is the decision-making body that approves the final drafts such as the national GHG inventory and country-specific emission and removal factors submitted after the consultation of the Working Group. The Management Committee, chaired by a Vice Minister of Environment, consists of not more than 15 members; director general-level officials from sectoral responsible ministries and Statistics Korea and for appointed members, experts from academia and the public sector.

[Figure 2-1] Organization for Preparation of the National GHG Inventory



1.2 Preparation Process

To enhance the transparency and accuracy of the national GHG inventory, the measurement and verification of inventory has been segregated and the review of the Working Group and the deliberation of the Management Committee has been performed step by step.

– Measurement and Reporting

The first step in preparing the national GHG inventory is to determine the methodology. To enhance the inventory quality, GIR prepares revised MRV Guidelines at the beginning of each year reflecting the areas for improvement identified during the verification process in the previous year. Once the revised MRV Guidelines are confirmed through the review of the Working Group and the deliberation of the Management Committee, GIR distributes it in March to the sectoral responsible ministries and measurement agencies. Afterward, based on the distributed MRV Guidelines, sectoral responsible ministries review their inventories estimated by the agencies and submit them to GIR by June 30.

– Verification

After collecting the inventory draft reports submitted by sectoral responsible ministries, GIR verifies measurement methodology, activity data, the appropriateness of emission and removal factors and detects any errors in the emission calculations of subcategories.

GIR requests these ministries to revise and complement their drafts by correcting errors and improving areas identified during the verification process. After confirmation of the inventory drafts that have been revised by the ministries, GIR prepares a final draft.

– Final Confirmation and Publication

GIR hosts the Working Group meetings for the review of the final draft of the inventory revised for each sector, and through the final deliberation of the Management Committee, the national GHG inventory is confirmed by December. Afterward, GIR publishes the approved national GHG inventory through several platforms including its website.

2. Measurement Scope and Method

2.1 Scope of Greenhouse Gases

The ROK's national GHG inventory includes the anthropogenic emissions and removals of GHGs defined by the Kyoto Protocol; carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrochlorofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Since greenhouse gases have different levels of heat dissipation for the residency period in the atmosphere, the national total emissions are expressed with CO_2 equivalent (CO_2eq.) calculated using the 100-year time horizon GWP for the purpose of understanding the levels and comparing each other. Meanwhile, the ROK calculated CO_2eq. of CH_4, N_2O, HFCs, PFCs, SF_6 using the GWP of the Intergovernmental Panel on Climate Change (IPCC) Second Assessment Report (SAR).

2.2 Scope of Sectors and Time Period

The ROK calculates the national GHG inventory for Energy, Industrial Processes, Agriculture, LULUCF, and Waste sectors in accordance with the IPCC Guidelines. Also, the report of the national GHG inventory covers 27 years from 1990 to 2016.

2.3 Measurement Methodology

The national GHG inventory was primarily prepared based on the 1996 IPCC Guidelines, but in some categories, the ROK applied the 2000 IPCC Good Practice Guidance (GPG 2000), 2003 IPCC Good Practice Guidance for LULUCF (GPG LULUCF), and 2006 IPCC Guidelines. The GPG 2000 was applied to (1) Civil Aviation in the Energy sector and (2) Landfills, Wastewater Treatment, and Waste Incineration in the Waste sector, and the IPCC GPG LULUCF and the 2006 IPCC Guidelines were applied to the LULUCF sector. The 2006 IPCC Guidelines were applied to the sub-sectors of (1) semiconductor and display manufacturing, and heavy electric equipment in the Industrial Processes sector, (2) rice cultivation

and agricultural soil management in the Agriculture sector, (3) above-ground biomass of forest land and wetlands in the LULUCF sector and (4) others in the Waste sector.

Also, the ROK continues to develop country-specific emission and removal factors (country-specific emission factors) to ensure the accuracy of the inventory. The use of country-specific emission factors is determined through MRV processes similar to the MRV processes for the national GHG inventory. In addition, the country-specific emission factors surveyed and analyzed by research institutes, etc., are submitted to GIR through the responsible ministry and then, GIR organizes a verification team consisting of experts in the Technical Group and internal experts to review the appropriateness of the development method, representativeness of factors, accuracy of measurement and analysis, etc. After verification, the emission factors are confirmed by the review of the Working Group and deliberation of the Management Committee.

In 2018, measurements were based on 70 country-specific emission factors, which accounted for about 80% of the total emissions. Country-specific emission factors were applied to the sectors of (1) Energy (33 factors) (2) rice cultivation and agriculture soil in Agriculture (13 factors), (3) forest land in LULUCF (6 factors), and (4) landfills, water waste treatment, and waste incineration in Waste (18 factors). Compared to the country-specific emission factors (57 in total) applied in the Second Biennial Update Report, 13 factors have been added in public electricity, heat production, and fugitive in the energy sector and sewage and wastewater treatment in the waste sector.

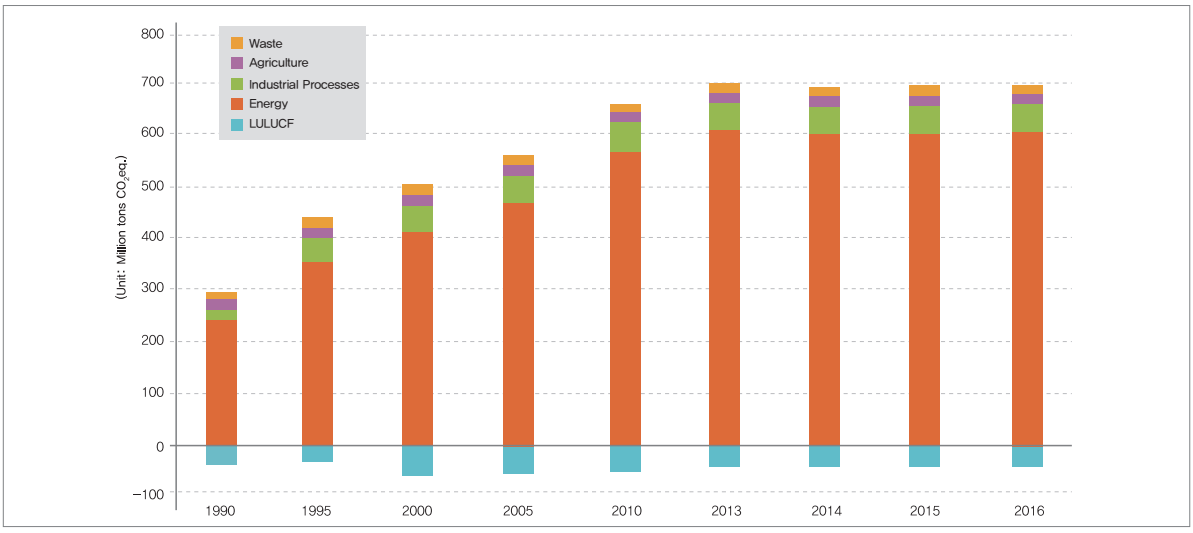
The emissions of sub-sectors not estimated with country-specific emission factors were mostly calculated with the default emission factors in the 1996 IPCC Guidelines and there were some sub-sectors to which the default emission factors in the 2006 IPCC Guidelines were applied. The default factors of the 2006 IPCC Guidelines were applied to the items of (1) fuel combustion of refinery gas and LPG fuel and fugitive emissions from oil and natural gas in the energy sector, (2) semiconductor and display manufacturing and heavy electric equipment in the industrial processes sector, (3) wetlands in the LULUCF sector, and (4) biological treatment of solid waste, etc., in the waste sector.

Meanwhile, the ROK is conducting research to build grounds in response to the mandatory application of the 2006 IPCC Guidelines under the Paris rulebook (confirmed at COP 24 in November 2018). Accordingly, since 2018, GIR has been conducting research and trial calculations with relevant authorities to improve the activity data, emission factors, etc., required to apply the 2006 IPCC Guidelines and plans to reflect these in future national GHG inventories.

3. Greenhouse Gas Emissions and Trends

The total GHG emissions in the ROK in 2016 were 694.1 million tons CO_2eq. and net emissions including sinks were 649.6 million tons CO_2eq. Total emissions in 2016 increased by 136.9% compared with 1990 and increased by 0.2% compared with 2015. The largest contributor to emissions growth in 2016 was the energy sector, which also accounted for the largest share of national emissions. This sector's GHG emissions increased by 2.4 million tons CO_2eq. compared to the previous year, due to increased emissions from road transport (4.4 million tons, by 4.9%), residential (1.8 million tons, by 6.0%), chemicals (1.4 million tons, by 3.8%), and petroleum refining (1.3 million tons, by 8.1%) sectors. It was analyzed that the increased emissions in road transport were due to increased fuel consumption caused by the increased number of registered vehicles (by 3.9%). The residential sector's increased emissions were mainly due to the increase in heating degree days[5] (130.6 heating degree days year-on-year, 5.3% increase[6]), and the increased emissions in chemical and petroleum refining sectors were due to the increased production caused by low oil prices (Dubai average $41/barrel[7]).

[Figure 2-2] Trends in National Greenhouse Gas Emissions and Removals (1990-2016)



5 The value of the accumulated daily difference between daily average temperature and the reference temperature of 18℃. If the daily average temperature is lower than the reference temperature, it is calculated as a heating degree day

6 Monthly Energy Statistics, Korea Energy Economics Institute, 2018

7 International oil prices (Dubai): $97/bbl in 2014, $51/bbl in 2015, $41/bbl in 2016 (Yearbook of Energy Statistics, 2017), bbl: Barrel (oil capacity unit, and 1 bbl is equivalent to about 159 liters)

〈Table 2-1〉 National Greenhouse Gas Emissions and Change

(Unit: Million tons CO_2eq.)

Sectors		1990	1995	2000	2005	2010	2013	2014	2015	2016
Total Emissions (excluding LULUCF)	Emissions	292.9	437.3	501.4	559.1	657.4	696.7	690.9	692.9	694.1
	Share (%)	100	100	100	100	100	100	100	100	100
	Change (%)	-	8.3	7.1	0.7	10	1.4	-0.8	0.3	0.2
Net Emissions (including LULUCF)	Emissions	254.7	406	442.2	504.3	603	652	648.3	650.1	649.6
	Share (%)	86.9	92.8	88.2	90.2	91.7	93.6	93.8	93.8	93.6
	Change (%)	-	9.6	7.3	1.2	11.6	2.2	-0.6	0.3	-0.1
Energy	Emissions	241.5	354.4	410.8	466.9	565.8	606.2	598.8	602.4	604.8
	Share (%)	82.4	81.0	81.9	83.5	86.1	87	86.7	86.9	87.1
	Change (%)	-	7.9	7.7	1.7	10.3	1.6	-1.2	0.6	0.4
Industrial Processes	Emissions	19.8	44.1	50.2	54.7	54.4	53.3	56	53.3	51.5
	Share (%)	6.7	10.1	10	9.8	8.3	7.6	8.1	7.7	7.4
	Change (%)	-	16	5.1	-5.5	14.3	0.6	5.1	-4.9	-3.4
Agriculture	Emissions	21.3	23.2	21.6	20.8	22.2	21.4	20.8	20.9	21.2
	Share (%)	7.3	5.3	4.3	3.7	3.4	3.1	3	3	3.1
	Change (%)	-	1.2	-2.8	0.8	2	-0.7	-2.8	0.8	1.6
LULUCF	Emissions	-38.2	-31.3	-59.3	-54.9	-54.4	-44.7	-42.7	-42.9	-44.5
	Share (%)	-13.1	-7.2	-11.8	-9.8	-8.3	-6.4	-6.2	-6.2	-6.4
	Change (%)	-	-6.1	5.5	-3.8	-4.7	-8.9	-4.6	0.5	3.7
Waste	Emissions	10.4	15.7	18.8	16.7	15	15.9	15.4	16.4	16.5
	Share (%)	3.6	3.6	3.8	3	2.3	2.3	2.2	2.4	2.4
	Change (%)	-	9.2	11.7	-5.5	-2.2	0.9	-3.2	6.4	1

Looking at the trend of the total emissions for each year, from 1990 to 1997, emissions increased by an average of 8.0% but in 2009, emissions increased only 0.8% year-on-year due to the economic downturn caused by the global financial crisis. However, in 2010, emissions increased by 10% year-on-year as the economy recovered and demands for industrial and heating power surged. Total emissions in 2013 reached a record high of 696.7 million tons CO_2eq. but in 2014, GHG emissions decreased by 0.8% from the previous year for the first time since the 1998 financial crisis. Since then in 2015 and 2016, emissions increased slightly by 0.3% and 0.2%, respectively.

3.1 Emission and Removal by Sector

– Energy

In 2016, the GHG emissions from the energy sector were 604.8 million tons CO_2eq., which accounted for 87.1% of the national GHG emissions. This represented a 150.5% increase compared with 1990 and a 0.4% increase from the previous year. Looking at the trend of emissions, after emissions increased from 1990 to 1997 but reduced following the economic crisis in 1998, they tended to rise again as the economy recovered. For the recent situation, the total emissions decreased by 1.2% in 2014, which marked the first time except 1998, the year of economic crisis and then, they increased by 0.6% and 0.4%, respectively, in 2015 and 2016.

By sub-sector, emissions from the transport, others, energy, and fugitive increased, while the manufacturing, construction, and unclassified sub-sectors decreased. The transportation sub-sector increased by 4.5 million tons CO_2eq. (4.8%) from the previous year, because emissions from road transportation, of which fuel consumption significantly increased due to a 3.9% increase in the number of registered vehicles and low oil prices, increased by 4.4 million tons CO_2eq. (4.9%). Meanwhile, emissions from the manufacturing and construction industries and unclassified sectors decreased by 2.7% to 5.2 million tons CO_2eq. and by 0.8% to 0.03 million tons CO_2eq., respectively, from the previous year. Such a sharp drop in emissions was attributable to a decrease in coking coal consumption in the manufacturing and construction sectors, which led to a 7.7% reduction, 7.8 million tons CO_2eq., from the previous year.

In terms of emission ratios, emissions from fuel combustion were 99.3% of the total emissions of the energy sector in 2016, and emissions from fugitive were 3.9 million tons CO_2eq., accounting for 0.7% of all emissions. Also, the shares of energy emissions by sub-sector in the energy sector were combustion (43.4%), manufacturing and construction (30.5%), transportation (16.3%), other sub-sectors (8.6%), and unclassified sectors (0.5%), and in the fugitive sector, they were oil and natural gas (0.6%) and solid fuels (0.1%).

〈Table 2-2〉 Greenhouse Gas Emissions by Energy Sector

(Unit: Million tons CO_2eq.)

Sub-sectors	1990	1995	2000	2005	2010	2013	2014	2015	2016
Total	241.5	354.4	410.8	466.9	565.8	606.2	598.8	602.4	604.8
1A Fuel combustion	236.4	352.0	408.2	463.8	562.0	601.7	594.7	598.6	600.9
1A1 Energy industry	47.9	91.8	135.1	177.5	255.8	274.1	259.3	261.5	262.8
1A2 Manufacturing industry and construction	76.6	116.9	129.9	134.9	161.8	182.5	194.7	189.4	184.3
1A3 Transportation	35.5	64.7	69.9	81.8	85.4	88.4	88.7	94.2	98.7
1A4 Others	76.3	75.7	70.9	66.3	56.0	53.7	49.2	50.4	52.1
1A5 Unclassified	0.2	2.8	2.4	3.2	2.9	3.0	2.9	3.1	3.1
1B Fugitive	5.1	2.4	2.7	3.1	3.8	4.5	4.1	3.8	3.9
1B1 Solid fuels	4.8	1.6	1.2	0.8	0.6	0.5	0.5	0.5	0.5
1B2 Oil and natural gas	0.3	0.8	1.5	2.3	3.2	4.0	3.6	3.3	3.5

– Industrial Processes

In 2016, the GHG emissions from the industrial processes sector were 51.5 million tons CO_2eq., which accounted for 7.4% of the national GHG emissions. This represented a 160.2% increase compared with 1990 and a 3.4% decrease from the previous year. Looking at the trend of emissions, they increased by an average of 13.9% from 1990 to 1997 but subsequently declined due to the economic crisis from 1998 to 2004, and increased again to the highest record (year 2004) in the industrial processes sector as the economy recovered. In addition, emissions generally declined from 2005 to 2009, when the global financial crisis hit, and there have been slight increases or decreases since

2010, recovering from the decrease, but the level was maintained until 2016. Emissions from the mineral industry were 34.8 million tons CO_2eq. in 2016, which accounted for 67.5% of the emissions from the industrial process sector. Emissions from the consumption of halocarbon and sulfur hexafluoride (SF_6) were 15.5 million tons CO_2eq. in 2016, which accounted for 30.2% of the emissions from the industrial process sector. In terms of emission trends, emissions from halocarbon and SF_6 consumption continued to increase from 0.2 million tons CO_2eq. in 1990 to 22.1 million tons CO_2eq., which was the highest since 1990. However, emissions have decreased from 2015 to the level of 15.5 million tons CO_2eq. in 2016, which is the same level as in 2005.

Emissions from the chemical industry were 0.9 million tons CO_2eq. in 2016, which accounted for 1.8% of the emissions from the industrial process sector. In terms of emission trends, the emissions from the chemical industry continued to increase since 1990 to 13.4 million tons CO_2eq. in 2004, which was the highest level. As the CDM reduction project for N_2O emissions was launched, the emissions began to decrease from 2004 and dropped by 86.5% year-on-year to 1.5 million tons CO_2eq., in 2007. Since then, the emissions have generally remained very low.

〈Table 2-3〉 Greenhouse Gas Emissions in Industrial Processes Sector

(Unit: Million tons CO_2eq.)

Sub-sectors	1990	1995	2000	2005	2010	2013	2014	2015	2016
Total	19.8	44.1	50.2	54.7	54.4	53.3	56	53.3	51.5
2A Mineral industry	18.2	31.5	28.6	28.1	31.3	32.5	33.6	34.2	34.8
2B Chemical industry	0.4	3.6	7.5	11.6	0.7	0.9	0.9	0.8	0.9
2C Metal industry	0.1	0.1	0.1	0.2	0.3	0.4	0.4	0.2	0.3
2E Production of Halocarbons and SF_6	1.0	2.6	3.2	0.000064	0.00013	0.00003	–	–	–
2F Consumption of Halocarbons and SF_6	0.2	6.1	10.7	14.9	22.1	19.5	21.1	18	15.5

– Agriculture

The GHG emissions from the agriculture sector were 21.2 million tons CO_2eq., which accounted for 3.1% of the national GHG emissions. This represented a 0.1% decrease compared with 1990 and a 1.6% increase from the previous year. An increase of emissions in livestock manure treatment, even though emissions from the rice cultivation sub-sector continued to decrease due to the decrease in cultivated acreage, was the reason for the increase in emissions compared with the previous year.

For emissions from the agriculture sector, emissions from the livestock sub-sector increased due to increased meat consumption and livestock manure processing, whereas emissions from the plowing and sowing sub-sector tended to decrease due to a reduction in rice cultivating area. Also, emissions from livestock manure processing and enteric fermentation in the livestock sub-sector increased by 2.5 million tons CO_2eq. (87.4%) and 1.2 million tons CO_2eq. (36.7%), respectively, compared with 1990. In addition, emissions

from the plowing and sowing sub-sector in 2016 decreased 23.5% from 1990, which was due to a 41.6% and a 39.3% reduction in rice cultivation and field burning of agricultural residues, respectively.

〈Table 2-4〉 Greenhouse Gas Emissions in the Agriculture Sector

(Unit: Million tons CO_2eq.)

Sub-sectors	1990	1995	2000	2005	2010	2013	2014	2015	2016
Total	21.3	23.2	21.6	20.8	22.2	21.4	20.8	20.9	21.2
Livestock subtotal	5.8	8.2	7.3	7.4	9.2	9.1	8.8	9.1	9.4
4A Enteric fermentation	3.0	4.1	3.4	3.3	4.3	4.4	4.2	4.1	4.0
4B Manure management	2.9	4.1	3.9	4.1	4.9	4.8	4.6	5.0	5.4
Plowing and sowing subtotal	15.4	14.9	14.2	13.4	13.0	12.2	12.0	11.9	11.8
4C Rice cultivation	10.5	9.1	8.7	8.0	7.3	6.4	6.3	6.2	6.1
4D Agricultural soils	4.9	5.8	5.6	5.4	5.7	5.8	5.7	5.6	5.7
4F Field burning of agricultural residues	0.033	0.025	0.029	0.027	0.024	0.021	0.021	0.021	0.02

– LULUCF

The LULUCF sector includes both GHG emission sources and sinks. In 2016, total absorption by forest land and grassland was −48.6 million tons CO_2eq., which was an increase of 23.8% compared to 1990 and total emissions from cropland and wetlands were 4.1 million tons CO_2eq., which was an increase of 321.1% compared to 1990. Net absorption was −44.5 million tons CO_2eq., and the ratio to total national emissions was 6.4% in 2016, which accounted for a 16.2% increase compared with 1990 and 3.7% compared with the previous year.

Looking at the share of emissions and removal in the LULUCF sector in 2016, among sinks, the forest lands' removal was −48.5 million tons CO_2eq., accounting for 99.9% of the total removal in LULUCF sector and the grassland's removal was −0.1 million tons CO_2eq., accounting for 0.1% of the total removal in the sector. In addition, among emission sources, the cropland sub-sector emitted 3.7 million tons CO_2eq., accounting for 91.2% of the total emissions from LULUCF sector, and the wetland sub-sector emitted 0.4 million tons CO_2eq., accounting for 8.8% of the total emission in the sector.

For change factors by sub-sector, the removal by forest land has been decreasing gradually since peaking in 2000 owing to continued reforestation. In 2016, forest trees increased by 2.8%, a 3.2% increase from the previous year. The emissions from cropland wholly increased to a peak in 2011 and have declined since then. The removal by grassland in 2016 showed an 89.8% decrease from 1990.

This is because there is no demand for new grassland since the ROK's livestock industry is dependent on the import of foreign feeds and because the area of grassland converted from other lands decreased due to agricultural and fishery land and various development projects. Meanwhile, emissions

from wetlands in 2016 increased by 21.6% compared with 1990 as the area of artificial flooded land increased.

〈Table 2-5〉 Greenhouse Gas Emissions and Removal in LULUCF Sector

(Unit: Million tons CO_2eq.)

Sub-sectors	1990	1995	2000	2005	2010	2013	2014	2015	2016
Total (net removal)	-38.2	-31.3	-59.3	-54.9	-54.4	-44.7	-42.7	-42.9	-44.5
5A Forest land	-38.7	-33.5	-62.2	-58.4	-59.4	-49.3	-47.2	-47	-48.5
5B Cropland	0.7	2.4	3.2	3.7	4.8	4.3	4.3	3.8	3.7
5C Grassland	-0.5	-0.6	-0.6	-0.4	-0.2	-0.1	-0.1	-0.1	-0.1
5D Wetlands	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4

- Waste

In 2016, the GHG emissions from the waste sector were 16.5 million tons CO_2eq., which accounted for 2.4% of the national GHG emissions, representing a 58.8% increase compared with 1990 and a 1.0% increase from the previous year. Among emissions from the waste sector, the waste landfills sub-sector emitted 7.6 million tons CO_2eq., accounting for 46.0% of the total emissions from the waste sector, and the waste incineration sub-sector emitted 7.1 million tons CO_2eq., accounting for 43.3% of the total emissions from the sector. In addition, the sewage and wastewater treatment sub-sector emitted 1.4 million tons CO_2eq., accounting for 8.6% of the total emissions from the waste sector, and the others emitted 0.4 million tons CO_2eq., accounting for 2.2% of the total emissions from the sector.

In terms of emissions by sub-sector, the emissions from incineration surged due to population and economic growth. Since then, as waste recycling became active by establishing the 2nd National Waste Control General Plan (2002-2011) in 2001, emissions gradually decreased. Emissions from the waste landfill sub-sector reached a peak of 10.4 million tons CO_2eq. in 1997 and have showed a downward trend since. The emissions decreased by 1.7% year-on-year in 2016, which was due to a 3.3% increase in the recovery of landfill gas. Emissions from sewage and wastewater treatment have maintained a similar trend since the mid-1990s and in 2016, they decreased by 4.3% compared with 1990 because the sewage treatment methodology was improved from biological treatment to advanced treatment.

〈Table 2-6〉 Greenhouse Gas Emissions in Waste Sector

(Unit: Million tons CO_2eq.)

Sub-sectors	1990	1995	2000	2005	2010	2013	2014	2015	2016
Total	10.4	15.7	18.8	16.7	15.0	15.9	15.4	16.4	16.5
6A Waste landfill	7.5	9.8	9.5	8.9	7.8	7.2	7.3	7.7	7.6
6B Sewage and wastewater treatment	1.5	1.8	1.5	1.6	1.5	1.4	1.4	1.4	1.4
6C Waste incineration	1.4	4.2	7.6	6.0	5.6	7.0	6.3	6.9	7.1
6D Others	-	0.002	0.1	0.2	0.2	0.3	0.3	0.3	0.4

3.2 Emission and Removal Trends by GHG

– Carbon dioxide (CO_2)

Total emissions of CO_2 (excluding LULUCF) reached 637.6 million tons CO_2eq. in 2016, accounting for 91.9% of the national GHG emissions. This represents a 152.7% increase compared with 252.3 million tons CO_2eq. in 1990. Meanwhile, the rates of change in emissions year-on-year in the last three years decreased by 1.1% in 2014, which was the first decrease in emissions since the 1998 financial crisis. However, the rate increased by 0.8% and 0.5% in 2015 and 2016, respectively.

The net emissions of CO_2 in 2016, including the LULUCF sector, were 592.8 million tons CO_2eq., which increased by 177.5% and by 0.3% compared with those in 1990 and in 2015, respectively. The shares of emissions by sector were 93.4% for the energy sector, 5.5% for the industrial processes, and 1.1% for the waste sector. In terms of emission trends by sector, the emissions from the waste sector in 2016 compared with 1990 showed an increase of 392.5%, the highest in the national emissions, followed by the energy sector (156.1%) and the industrial processes sector (91.3%). The CO_2 net removal in the LULUCF sector increased by 15.6%.

In 2016, the percentage change in CO_2 emissions increased by 0.4%, 1.7% and 4.5% in the energy, industrial processes, and waste sectors, respectively, from the previous year. In the LULUCF sector, net removal increased by 3.7% compared with the previous year.

〈Table 2-7〉 CO_2 Emissions and Removal by Sector

(Unit: Million tons CO_2eq.)

Sub-sectors		1990	1995	2000	2005	2010	2013	2014	2015	2016
Total CO_2 emissions (excluding LULUCF)		252.3	385.2	441.6	494.5	594.7	636.4	629.7	634.5	637.6
Net CO_2 emissions (including LULUCF)		213.6	353.6	382.1	439.3	540.0	591.3	586.7	591.3	592.8
1. Energy	1A1 Energy industry	47.6	91.3	134.4	176.5	254.4	272.5	257.8	260.0	261.3
	1A2 Manufacturing industry	76.1	116.1	128.9	133.8	160.4	180.9	192.8	187.5	182.4
	1A3 Transportation	35.3	64.3	69.4	81.2	84.7	87.7	88.0	93.5	98.0
	1A4 Others	73.5	74.9	70.3	65.7	55.4	53.0	48.4	49.5	51.1
	1A5 Unclassified	0.2	2.8	2.4	3.2	2.9	3.0	2.8	3.1	3.1
2. Industrial processes	2A Mineral industry	18.2	31.5	28.6	28.1	31.3	32.5	33.6	34.2	34.8
	2B Chemical industry	0.002	0.004	0.03	0.01	0.002	0.002	0.002	0.002	0.002
	2C Metal industry	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.1	0.2
5. LULUCF (net removal)		-38.7	-31.6	-59.6	-55.2	-54.7	-45.1	-43.0	-43.2	-44.8
6. Waste		1.4	4.1	7.4	5.8	5.4	6.7	6.0	6.6	6.9

– Methane (CH_4)

Total emission of CH_4 (excluding LULUCF) was 26.0 million tons CO_2eq. in 2016, accounting for 3.7% of the national GHG emissions (excluding LULUCF). It decreased by 14.2% compared with emissions of 30.3 million tons CO_2eq. in 1990 but increased by 0.02% compared with the previous year.

In 2016, CH_4 net emissions (including LULUCF) were 26.3 million tons CO_2eq., accounting for 4.0% of national GHG net emissions (including LULUCF). For the shares of emissions by sector, the agricultural sector accounted for 43.7%, followed by waste 30.6%, energy 22.4%, industrial processes 2.2% and LULUCF 1.1%.

– Nitrous oxide (N_2O)

The total emissions of N_2O (excluding LULUCF) were 14.8 million tons CO_2eq. in 2016, accounting for 2.1% of the national GHG emissions (excluding LULUCF). This represented a 62.0% increase compared with 9.2 million tons CO_2eq. in 1990 and a 3.6% increase compared with 14.3 million tons CO_2eq. in 2015

In 2016, N_2O net emissions (including LULUCF) were 14.9 million tons CO_2eq., accounting for 2.3% of national GHG net emissions (including LULUCF). For the shares of emissions by sector, the agricultural sector accounted for 65.5%, the largest share, followed by energy 21.1%, waste 10.9%, industrial processes 2.2% and LULUCF 0.3%.

– Hydrochlorofluorocarbons (HFCs)

The emissions of HFCs were 7.4 million tons CO_2eq., accounting for 1.1% of the national GHG emissions (excluding LULUCF). This represented a 649.5% increase compared with 1990 and a 7.1% decrease compared with the previous year. All HFCs are emitted in the industrial processes sector with the sub-sectors of halocarbon and sulfur hexafluoride production and consumption.

HFCs emissions have been steadily increasing since 1990, but sharply dropped through the Clean Development Mechanism (CDM) project, which was implemented from 2003 to 2013 in the halocarbon and sulfur hexafluoride production sectors. In 2016, 97.4% of the total HFC emissions were generated by refrigeration and cooling use, with reports that 2.6% were generated by semiconductor and LCD manufacturing.

– Perfluorocarbons (PFCs)

The emissions of PFCs were 1.5 million tons CO_2eq., accounting for 0.2% of the national GHG emissions (excluding LULUCF). This represented a 539,488.7% increase compared with 1992, the first measurement year, and a 2.1% decrease compared with the previous year. All PFCs are emitted in the industrial processes sector.

PFC emissions are generated from the halocarbon and sulfur hexafluoride consumption sectors in industrial processes. In terms of emission trends, PFC emissions generally increased from 1997 to 2007 and temporarily decreased by 26.7% year-on-year due to the economic downturn in 2009. Since then, PFC emissions, which were on the rise after 2011, have decreased since 2015 because reduction activities in the semiconductor and LCD manufacturing industry have expanded.

– Sulfur hexafluoride (SF_6)

Emissions of SF_6 were 6.8 million tons CO_2eq., accounting for 1.0% of the national GHG emissions (excluding LULUCF). This represented an increase of 3,810.5% compared with 1990 and a decrease of 21.8 % compared with the previous year. All SF_6 are emitted in the industrial processes sector.

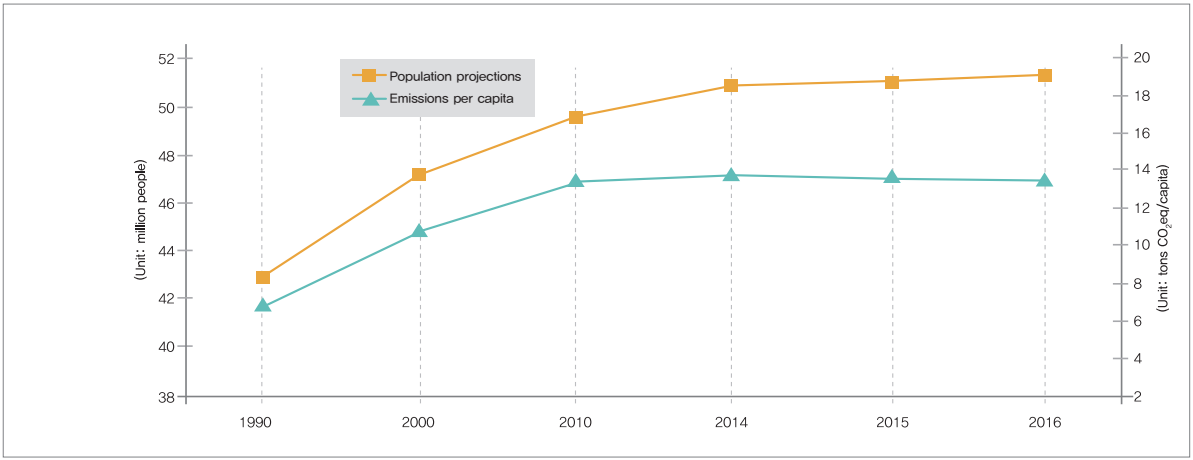
SF_6 is generated from the consumption of halocarbon and sulfur hexafluoride in the industrial process sector and the metals sector and the share of the halocarbon and sulfur hexafluoride consumption accounts for 98.2%. Emissions from the halocarbon and sulfur hexafluoride consumption are generated during the manufacturing process of semiconductors and LCDs and from the installation, use, and disposal of heavy electric equipment. For the emission sources of sulfur hexafluoride, the manufacture of semiconductors and LCDs accounts for 48.1% of the emissions and the production, use, and disposal of heavy electric equipment accounts for 50.1% of the emissions, which appear to be the majority. All SF_6 emissions from the metal sub-sector are generated from magnesium production, accounting for 1.8%.

3.3 Trends of Emissions per Capita and GDP

– Greenhouse Gas Emissions per Capita

In 2016, the ROK's total greenhouse gas emissions per capita were 13.5 tons CO_2eq., which was about twice that of 1990. This increase in per capita GHG emissions was caused by a significant increase in industrial development rather than population growth. However, the growth of GHG emissions has slowed since 2012, and GHG emissions per capita changed to a decreasing trend. With the exception of the economic crisis in 1998, the decline over the last three years is the first case since 1990.

[Figure 2-3] Greenhouse Gas Emissions per Capita and Estimated Population (1990-2016)



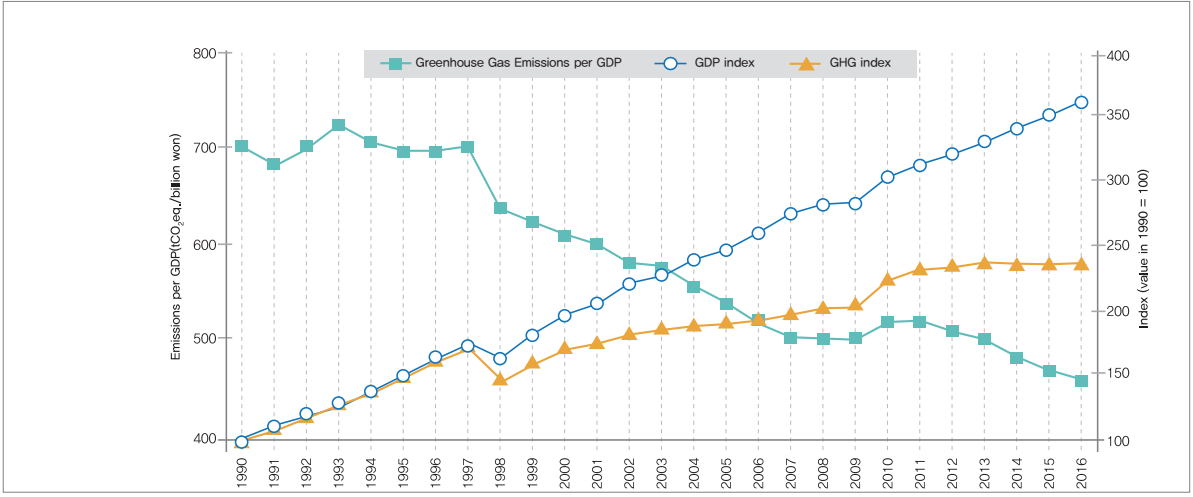
※ Source: Population Projections for the ROK (Statistics Korea, 2018)

- GHG Emissions per Real GDP

Total GHG emissions per 2016 GDP (2015) calculated based on GDP data published by the Bank of Korea in 2018 were 459.7 tons CO_2eq./billion won. This represented a 34.2% decrease compared with 698.3 tons CO_2eq./billion won in 1990, and a 2.7% decrease compared with 472.4 tons CO_2eq./billion won in 2015.

Looking at the trend from 1990 to 2016, total GHG emissions and GDP increased at similar rates from 1990 to 1997, but both total emissions and GDP decreased during the financial crisis in 1998. Both indicators have turned upward since 1998. As the GDP growth rate increased more than the total GHG emission increase rate, however, the total GHG emissions per GDP tended to decrease. In 2010 and 2011, the total GHG emissions per GDP increased compared with the previous year in the course of the recovery of the worsened economy in 2009. However, the trend turned downward from 2012.

[Figure 2-4] Greenhouse Gas Emissions to GDP (1990-2016)



※ Source: National Account (as of 2010), Real GDP by Economic Activity, Bank of Korea, 2018

[Hemispherical Sundial] Concave Pot-shaped Sundial in the Joseon Dynasty period

CHAPTER 3

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Mitigation Policies and Actions

1. Emission Projections and Reduction Target
2. Mitigation Actions by Sector

1. Emission Projections and Reduction Target

1.1 Emission Projections

– Trends of GHG Emission and Energy Demand

The long-term GHG emission projections for the ROK, where the GHG emissions of the energy sector accounted for more than 85% (87.2% in 2012) of total emissions, were prepared using the 3rd Energy Master Plan (2019), which included energy demand projections through 2040, and the 8th Master Plan for Electricity Supply and Demand (2017), as basic data for analysis. Industrial processes and agricultural, livestock sectors, etc., which were not included in the Energy Master Plan, were newly projected for 2030 using the latest data.

The ROK's industrial structure shows modest growth in energy-consuming sub-sectors such as steel and petrochemicals, and it was expected that the assembly metal industry such as machinery, automobiles, and semiconductors will lead the economic growth.

The total energy demand of the ROK over the forecast period is expected to increase at an annual average rate of 0.6%. Energy consumption will finally increase from 176.0 tons of oil equivalent (TOE)[8] in 2017 to 211.0 TOE in 2040, but the energy basic unit is expected to decrease from 0.113 TOE/million in 2017 to 0.087 TOE/million in 2040, improving by 1.1% annually, resulting from improved energy efficiency.

For sectoral energy consumption, the commercial sector is expected to drive the growth of energy demand. On the other hand, the growth of energy-consuming industries such as petrochemicals will slow, but overall energy demand will increase at an annual average rate of 0.89%, with the share of the energy sector declining gradually after 2020. The transportation and residential sectors are also expected to have a modest increase in energy demand as economic growth and population growth slows.

– Emission Projections by Sector

The ROK's GHG emissions projection for 2030 is 850.8 million tons CO_2eq., increasing at an annual average rate of 1.33% over the forecast period. Among them, the energy sector will account for 86.9% of the total emissions with 738.9 million tons CO_2eq. in 2030, increasing at an annual average rate of 1.32% over the forecast period, and the emissions of non-energy sectors are expected to be 111.7 million tons CO_2eq. in 2030, increasing at an annual average rate of 1.31% over the forecast period. Emission growth rates in both the energy and non-energy sectors are expected to decrease slightly after 2020.

8 TOE (Ton of Oil Equivalent): Based on the calorific values of all energy sources existing on the planet, they are converted to the calorific value of petroleum, which is in units of energy called ton of oil equivalent. Virtual unit for comparing units of various energy

〈Table 3-1〉 Greenhouse Gas Emission Projections Results

(Unit: Million tons CO_2eq.)

Descriptions	2013	2020	2030	Annual average growth rate (%)	
				2013-2020	2013-2030
Energy sector	592	678	739	1.94	1.32
Non-energy sector	88	105	112	2.59	1.43
Total	680	783	851	2.03	1.33

※ Because of changing the GHG statistics standard in 2012, 776.1 million tons CO_2eq., BAU level in 2020 is equivalent to 764.1 million tons CO_2eq.

Reflecting the rapid growth of the assembly metal industry, which has a high demand for electricity, and the entry of new coal-fired power plants, GHG emissions from the energy transformation sector are expected to increase somewhat faster for the years from 2013 to 2020. In the meantime, emissions from the sector are expected to grow 2.1% over the whole period as the increase rate slows after 2021. Emissions from the industrial sector are expected to increase slowly at an annual average rate of 0.7% as the growth of energy-consuming industries (petrochemicals, steel, non-metallic minerals) are stabilized. The increasing rates of emissions by the transport, residential, and commercial sectors are expected to slow or even decrease slightly due to the stabilization of economic growth and population stagnation.

〈Table 3-2〉 Greenhouse Gas Emission Projections Results

(Unit: Million tons CO_2eq.)

Descriptions	2013	2020	2025	2030	Annual average growth rate (%)	
					2013-2020	2013-2030
Total (A+B)	680	783	809	851	2.03	1.33
Energy total (A)	592	678	700	739	1.94	1.32
Non-energy total (B)	88	105	109	112	2.59	1.43

1.2 National GHG Reduction Target and Roadmap

To solve the problem of climate change, the international community continues to make efforts, such as holding the rising global temperature to within 2℃, by concluding the Climate Change Convention with information on GHG emission reduction obligations and goals.

After having declared Low Carbon Green Growth as the national vision in 2008, the ROK for the first time established the national GHG reduction target for 2009 and announced a mid-term national GHG reduction target to reduce emissions by 30% from the business-as-usual (BAU) level by 2020. Since then, the ROK organized and operated the Joint Working Group composed of relevant ministries around GIR. The Working Group determined yearly reduction targets for 25 sub-sectors in 7 sectors through 2020 in 2011 and established in 2014 a Roadmap to Achieve the National GHG Reduction Target for 2020 which contains action plans by sector to achieve the yearly targets.

During the course of such progress, the agreement for the new post-Kyoto climate regime joined by developed and developing nations had gained momentum, and the opinion to set a reduction target beyond 2020 became popular. In 2015, the ROK organized and operated the Post-2020 Joint Working Group around 15 specialized agencies including GIR to confirm a target to reduce emissions by 37% from the BAU[9] level as the national GHG reduction target for 2030.

For the fulfillment of the target, the ROK is making efforts to reduce GHG emissions by enacting relevant laws and enforcement decrees and establishing related institutions. Major activities for coping with climate change can be classified into laws, institutions, capacity building, international cooperation, and response systems.[10]

In particular, the ROK must exert great efforts to curb emissions while facing the challenges of a high share of manufacturing in its industries and an energy efficiency level[11] that has already reached a relatively high standard of advancement. Globally, the Paris Agreement, as the basis for the post-2020 new climate regime, was adopted in December 2015 and went into effect in 2016, establishing a universal climate change response system with almost all nations in the global community participating.

According to these domestic and foreign conditions, the ROK presented specific policy directions for 8 sectors and 30 sub-sectors to implement the reduction targets and established the Roadmap to Achieve the National GHG Reduction Target for 2030 (2030 Roadmap) in 2016, which contains sectoral reduction plans and implementation evaluation plans to effectively implement these policies.

Means for achieving reduction targets are divided into two categories; the reduction of emission sources by sector such as industry, building, and transportation and the method using reduction measures such as the transformation sector, new energy industry, forest sinks, and overseas reduction. The evaluation system consists of two methods—evaluating the implementation of specific strategies, such as reduction measures and policies, and a comprehensive evaluation of the implementation for the national reduction target. In addition, based on evaluations led by ministries responsible for each sector, the OPC (Office for Government Policy Coordination) carries out comprehensive monitoring and evaluation of the overall implementation progress.

9 BAU (Business-As-Usual) Estimates of future emissions, assuming no additional GHG reduction measures in addition to current policies.

10 The 1st Climate Change Response Master Plan, Jointly by relevant Ministries, 2016

11 Compared with the energy efficiency of major countries based on production, the ROK is in the high level of efficiency; the world's No. 2 in the steel industry (0.18 TOE/ton) and the world's No. 1 in chemical and petrochemicals (1.22 TOE/ton). Source: Analysis of GHG Reduction Potential Considering Technological Competitiveness and Possibility of Technology Transfer for the COP20, Korea Energy Economics Institute, 2014

Since then, to reflect changes in atmospheric and energy policies and achieve the national GHG reduction target promised to the international community without disruption, the government established the Amendment to the Roadmap to Achieve the National GHG Reduction Target for 2030 (the Amendment to the 2030 Roadmap) jointly with relevant ministries in 2018.

The amendment to the 2030 Roadmap minimized the amount of overseas reductions due to uncertainty regarding implementation and increased domestic reduction targets, to be achieved by reinforcing energy demand management in each sector, promoting energy efficiency and fostering low carbon industries.

〈Table 3-3〉 Amendment to the Roadmap for the National GHG Reduction for 2030

(Unit: Million tons, %)

Sub-sectors		BAU	Reduction compared to BAU	Reduction rate compared to BAU
Reduction Measures	Total	850.8	-314.8	37.0%
	Domestic Reduction	-	-276.4	32.5%
	Overseas Reduction	-	-38.3	4.5%

The 2030 Roadmap specifies the emissions projection, reduction target and major reduction plans for 30 sub-sectors within 8 sectors. According to the roadmap, the greatest quantity of the reductions will be derived from energy transformation, followed by industry and buildings; while the sectors showing the highest rate of reductions is transportation, followed by waste and energy transformation.

To improve the feasibility of the 2030 Roadmap under the new climate regime, the roadmap will continue to be complemented and revised until 2020 when the NDC is to be submitted. During this process, the ROK plans to review reduction measures and adjust reduction pathways considering the changes in circumstances, such as emission results, economic conditions, international negotiation outcomes, and revision of related plans. It will also continue to prepare a plan to procure emission allowances by utilizing international carbon markets. Moreover, the ROK plans to present the GHG reduction implementation evaluation system that includes the establishment of a feedback system, such as the development of evaluation techniques and index and budget support for major reduction measures, and the improvement of the national GHG inventory system.

- Policy Decision Process

In November 2009, the ROK established and pledged the international community that it would reach the goal of reducing greenhouse gas emissions by 30% of the BAU level by 2020. The reduction level of the target was set

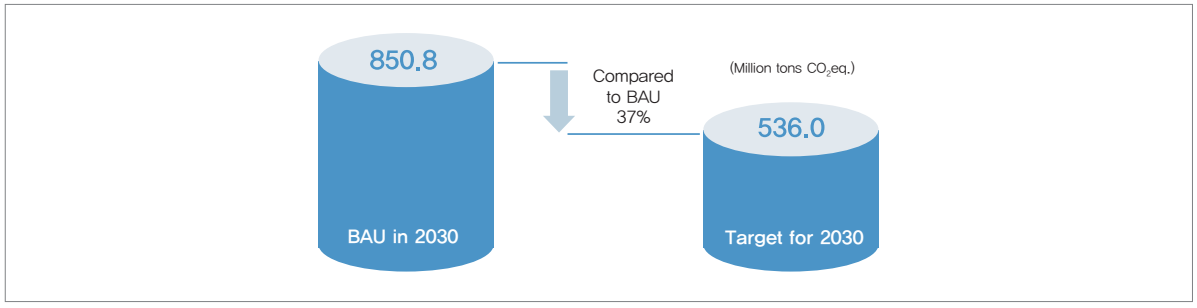
taking into account international recommendations (IPCC is △15%–△30% compared to BAU), and the BAU method was introduced. According to this, the ROK established the Roadmap to Achieve the National GHG Reduction Target for 2020 to present a national greenhouse gas reduction roadmap in January 2014, and yearly and sectoral implementation plans to achieve the national reduction target. However, since establishing the 2020 Reduction Roadmap, GHG emissions by the ROK reached 690.9 million tons in 2014, 692.9 million tons in 2015, and 694.1 million tons in 2016.

Meanwhile, the Paris Agreement, as the basis for the post–2020 new climate regime, was globally adopted in 2015 and went into effect in 2016 to establish a universal climate change scheme with almost all nations in the global community participating. Accordingly, there was a need to establish reduction targets beyond 2020. Therefore, the ROK organized and operated the Post–2020 Joint Working Group, which confirmed the target of reducing greenhouse gas emissions by 37% from BAU level by 2030 in 2015 including domestic reductions and overseas reductions using the international carbon market, and submitted it to the UN.

In accordance with these domestic and overseas conditions, the ROK presented specific policy directions to implement the reduction targets through consultations between private and public sectors, such as relevant associations, organizations, and major corporations around the ministries and offices concerned and established the 2030 Roadmap in 2016, and the amendment of the 2030 Roadmap in 2018 to effectively implement these policies.

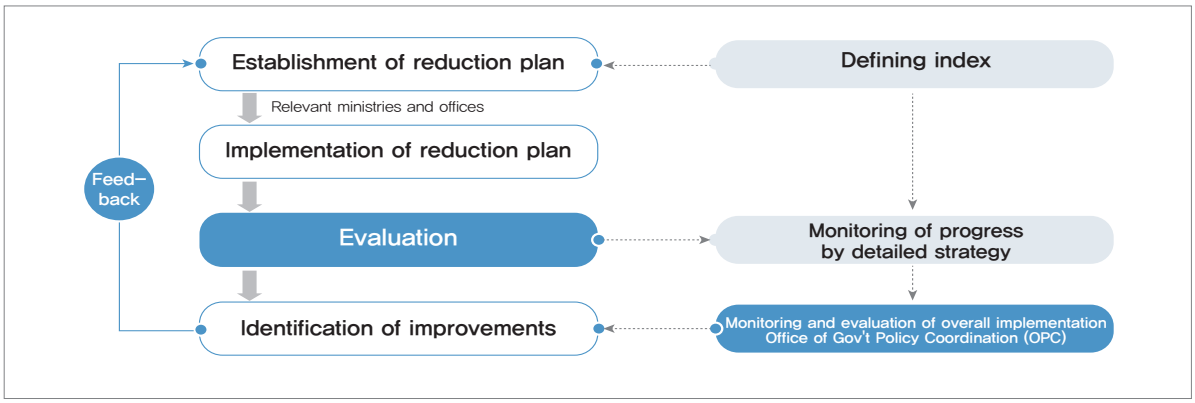
In accordance with the amendment to the 2030 Roadmap, the ROK set the national GHG emissions at 536.0 million tons CO_2eq., which is 37% lower than the BAU level and 22.3% lower than in 2015. It also committed itself to a further reduction in GHG emissions through the use of forest sinks, overseas reductions and other methods in addition to domestic reductions in each sector. The ROK will fulfill its detailed plan with due consideration to trends arising from follow–up measures to the Paris Agreement.

[Figure 3–1] National GHG Reduction Target for 2030



To enhance the predictability of future reduction policies and strengthen the implementation management of the reduction targets, the ROK will set intermediate goals every three years by gathering opinions of experts and civil communities on the linkage with the allocation period of the emissions trading system and the feasibility, etc., of the path target performance management during the remaining years of the target year, 2030.

[Figure 3-2] 2030 Roadmap Evaluation System



– Transformation Sector

Major reduction measures in the transformation sector may be divided into the improvement of power generation infrastructure, reinforcement of environment-friendly power generation mix, utilization of collective energy and potential reductions, etc.

As the Energy Transformation Roadmap, the basic direction of energy policy, was finalized in 2017, the ROK set goals such as the phase-out of nuclear power plants and expansion of renewable energy to 30-35% of power generation by 2040. To construct a safe and environment-friendly power mix, the Roadmap reveals plans to phase out nuclear power and coal-fired power plants and increase the share of renewable energy and LNG.

The improvement of power generation infrastructure is to reduce GHG emissions by the early retirement of 10 old coal-fired power plants by 2022, conversion of 6 coal-fired power plants to LNG for the years 2023 to 2030, and expansion of LNG and pumping-up power generation. In addition to these, the proportion of renewable energy generation is raised to 30-35% and the Coal Power Plant Shutdown Program in Spring is introduced to shut down coal-fired generators older than 30 years in the spring season (March to June) when yellow dust and fine dust are most severe.

The sector also continues to promote the conversion to environment-friendly energy, such as expansion of the use of collective energy by recovering unused energy and activating heat linkage between business entities,

upper bound constraint in spring[12], replacement of bio heavy oil, use of high-calorie coal, tax reform on power generation fuels, reinforcement of dispatch, considering environmental cost, and reduced reliance on coal-fired generation to lessen fine dust levels, and to promote innovative ways to reduce GHG emissions for continued reductions.

– Industrial Sector

The industrial sector will reduce GHG through measures, such as ① the improvement of energy efficiency (37.8 million tons CO_2eq.) by improving common equipment efficiency, distributing the Factory Energy Management System (FEMS)[13]), and improving process facilities, ② conversion to high value products by the development and distribution of new technology and innovative technology (21.9 million tons CO_2eq.), ③ the development of environment-friendly process gas and replacement of refrigerants (17.0 million tons CO_2eq.), ④ replacement with fuels and materials having low GHG emissions (4.4 million tons CO_2eq.), and ⑤ the use of waste resources including waste heat and waste (3.1 million tons CO_2eq.).

To improve energy use efficiency, this sector expands the supply of high-efficiency equipment through the High-efficiency Energy Equipment Certification System and the implementation of mandatory production and sales of premium electric motors (IE3) in 2015 and mandatory FEMS installations for plants of a certain size and the exemption of examination obligations when installing EMS.

In addition, the sector induces refrigerants with high global warming indexes to refrigerants with low global warming index and at the same time, supports technology development of environment-friendly refrigerants. The sector also replaces the process gas used in semiconductors and displays with NF3 or non-greenhouse gas with a low global warming index and supports the installation of facilities to reduce greenhouse gases used in the process.

– Buildings Sector

The building sector will reduce GHG emissions through measures such as ① reinforcement of policies including new building permit standards (5.5 million tons CO_2eq.), ② improvement of existing buildings' energy performance (9.6 million tons CO_2eq.), ③ improvement of facility efficiency and expansion of renewable energy supply (15.2 million tons CO_2eq.), ④ construction of building energy information infrastructure and promotion of consumption improvement (5.8 million tons CO_2eq.).

12 Restricting coal-fired power generation output when a fine dust alarm is issued by the Mayor/Do Governor

13 FEMS (Factory Energy Management System): System that maximizes productivity and energy efficiency through integrated management of factory production facilities and non-production facilities

The sector enhances the permit criteria for new buildings, such as strengthening building energy standards, implementing phased mandatory zero-energy buildings, and improving the construction standards and performance of energy-saving environment-friendly houses. Along with this, the sector expands regional projects such as mandating the performance improvement of less energy-efficient public buildings and discovering models of urban regeneration linkage projects. The sector also supports policies to improve energy performance for existing buildings, such as the establishment and implementation of mid- and long-term plans to activate green remodeling and project planning support and financial expansion to improve the energy performance of old private buildings.

The sector improves energy consumption efficiency classes and equipment efficiency related to home appliances, office equipment, and facilities and expands the distribution of renewable energy for houses and buildings through renewable energy support projects. The sector also induces the development and provision of customized services for energy saving through IoT and big data analysis, development of building energy performance management guidance online service and energy-saving manuals for each purpose, development of building energy management system (BEMS[14]) technology, building of energy information infrastructure, improving consumption, etc.

– Transportation Sector

The transportation sector will reduce GHG emissions through measures such as ① broad distributions of electric vehicles, reinforcement of average fuel efficiency standards, introduction of an average fuel efficiency system for medium and large vehicles, commercialization of electric buses (23.1 million tons CO_2eq.), ② Improvement of energy efficiency in the shipping sector, including the distribution of environment-friendly ships (0.2 million tons CO_2eq.) ③ expansion of public transportation (1.8 million tons CO_2eq.), ④ implementation of telework, increase of economic driving rate, restriction of passenger car operation (1.6 million tons CO_2eq.), ⑤ efficiency of green logistics (1.8 million tons CO_2eq.), ⑥ Biodiesel 3.0 standard for cars (1.2 million tons CO_2eq.), ⑦ emission trading system for air transportation and efficiency improvements of aircraft (0.2 million tons CO_2eq.).

For vehicles, the sector provides grounds for disseminating environment-friendly vehicles such as hybrid electric vehicles (HYB) and fuel cell electric vehicles (FCEV), gradually increase the proportion of environment-friendly vehicles by technology development and subsidies, and strengthens the average fuel efficiency of passenger vehicles and commercialize electric buses with both wired and wireless charging options instead of diesel and CNG city buses.

14 BEMS: Building Energy Management System

For vessels, the sector improves energy efficiency by the introduction of LNG/LPG fuel propulsion for new ships, expansion of linear optimization and the use of Alternative Maritime Power Supply (AMP), design and renovation of bow parts of existing ships, installment of high-efficiency propellers, use of low-friction hull paint, scrapping of obsolete ships, etc. For aviation, the sector lays the groundwork for improving aircraft operating efficiency (1.0% annual increase in air-fuel efficiency) and raises efficiency by improving air traffic control and airport operations.

For railways, the sector extends and expands BRT (Bus Rapid Transit), operates transit centers and districts restricted to public transportation, increases the share of railway transportation by expanding urban/metropolitan railway networks and expanding national high-speed railway operations. In addition, this sector makes green logistics efficient by the activation of 3rd party logistics including the logistics collaboration support project, subsidies to convert road freight into rail and shipping, and reinforcement of the combined inter-modal transportation system for D2D Service.

– Waste Sector

The waste sector will reduce GHG emissions through measures ① waste reduction and recycling expansion (4.2 million tons CO_2eq.), ② landfill methane gas recovery (0.5 million tons CO_2eq.).

To promote the reduction and recycling of waste by type, comprehensive improvement measures are implemented at each stage from production to consumption, waste management, and recycling stages. In addition, the sector operates facilities to recover methane gas generated from managed landfills such as metropolitan landfills and to produce energy using the gas to reduce GHG emissions.

– Public and Other Sectors

The public and other sectors will reduce GHG through measures such as ① distribution of LED lighting and street lights (2.35 million tons CO_2eq.), ② distribution of renewable energy facilities (1.2 million tons CO_2eq.), ③ reinforcement of building insulation (0.3 million tons CO_2eq.), ④ introduction of energy management systems for new and extended buildings (0.6 million tons CO_2eq.).

As the number of public institutions subject to the LED Lighting Plan for 2060 and the 4th and 5th Energy Use Rationalization Master Plans increases (government offices, public offices, elementary, middle and high schools, and universities), the sector raises the penetration rate of LED lighting from the existing 90% to 100%. Alongside this, the sector replaces 70% of street lamp electricity consumption with LED street lights and the remaining 30% with

renewable energy street lights.

The sector expands the distribution of renewable energy facilities, such as applying the supply plan of solar thermal 23.5 kilotons of oil equivalent (KTOE) and geothermal 278.6 KTOE by 2030. In addition, the sector will phase in passive technology[15] in 2020 and zero energy technology[16] in 2027 for new buildings to strengthen building insulation and introduce BEMS for new and extended buildings to distribute the system at an annual average of 3% to public institutions (37% penetration in 2030) and achieve energy savings at an annual average of 10%.

– Agricultural and Livestock Sector

The agricultural and livestock sector will reduce GHG through measures such as ① development and distribution of technology for reduced paddy field management (0.3 million tons CO_2eq.), ② expansion of livestock manure energy and related facilities (0.4 million tons CO_2eq.), and ③ expansion of feeding livestock with high-quality bulk feed and supply of low-methane feed (0.2 million tons CO_2eq.).

In the farming sector, the reduction is made mainly by policy projects due to the nature of agriculture, where a large number of unspecified small farms are the source of GHG. The sector encourages farmers to practice intermittent irrigation and water-saving irrigation when cultivating aquatic rice through training, etc., in agricultural technology centers. The livestock sub-sector reduces GHG emissions by improving livestock manure treatment efficiency and biogas production efficiency by improving cleanup systems and pretreatment procedures and developing technologies for the operation of digestion facilities.

15 Reduction of cooling and heating energy load by strengthening the performance of insulation such as lighting, ventilation, and insulation

16 Minimization of building energy load by maximizing thermal insulation performance (passive) and the minimization of building energy requirements by using renewable energy such as solar (active)

2. Mitigation Actions by Sector

2.1 General Reduction Policy

– Emissions Trading System

The ROK established a legal basis by enacting the Act on the Allocation and Trading of Greenhouse Gas Emission Permits and the Enforcement Decree of the same Act in 2012 and introduced an emissions trading system to 525 companies for Phase I (2015–2017) on January 2015. The government suggested a basic direction, main targets, and detailed operational directions for each phase[17] with the goal of "effectively achieving national GHG emission reduction targets" to operate the emissions trading system pursuant to the five fundamental principles stipulated in Article 3 of the Act. In addition, the government established and announced the National Emission Allowance Allocation Plan for Phase I (2015–2017) of the GHG Emissions Trading System in 2014, which includes details such as the sectors and sub-sectors eligible for allocation, total number of emission allowances, numbers allocated to each sub-sector, allocation standards for each entity, and emission allowances in reserve, pursuant to Article 2 (1) of the Enforcement Decree of the Act, considering the compatibility of the 1st Master Plan with the national GHG reduction targets.

The main targets of the system for each phase presented in the Master Plan for the Emissions Trading System (2014) (the 1st Master Plan) are as follows. The 1st Master Plan stipulated the government's progressive and stable system operation plan as the settlement of the emissions trading system during Phase I, the effective reduction of greenhouse gases during Phase II, and the active reduction of GHG during Phase III, and provided long-term system standards to stakeholders such as business entities eligible for allocation.

The 2nd Master Plan for the Emissions Trading System (2017) (the 2nd Master Plan) aimed to achieve the same target of "effectively achieving national targets for reducing greenhouse gases." In the 2nd Plan, three sub-operational strategies were established: promoting low-carbon industry innovation and green investment, reducing greenhouse gases in cost-effective and flexible ways, and achieving national reduction targets and preemptively supporting international carbon markets. While the First Master Plan intended to present the direction of operation for each phase based on the five basic principles because it was in the early stage of implementation, the Second Master Plan further specified the government's policy direction by dividing the operational planning direction into five areas: allocation

17 ① Complying with the principles set forth in the United Nations Framework Conventions on Climate Change and relevant protocols and considering international negotiations on climate change, ② considering the impact of an emissions trading system on the international competitiveness of economic sectors, ③ making the most of market mechanisms to achieve national greenhouse gas reduction targets effectively, ④ ensuring that emission permits are traded in a fair and transparent manner in accordance with general trading rules, and ⑤ implementing policies that are suitable to international standards, considering the linkage with international carbon markets.

of allowances, emission reduction using external projects, verification and certification of emissions, emission trading market, international cooperation and industrial support. The ROK decided that it would resolve the emissions that are difficult to reduce with domestic reduction measures by using forest sinks and overseas reductions, and that the detailed plan for it would be established by reflecting the results of the follow-up negotiations of the Paris Agreement.

〈Table 3-4〉 Operational Directions for Each Phase under the 2nd Master Plan

Descriptions	Phase I (2015-2017)	Phase II (2018-2020)
Allocation of allowances	• Applying GF[18] method – Applying BM[19] method to three sub-sectors • Fully free allocation	• Expanding the BM method – Leading to improve facility efficiency • Implementing allocation at a cost (3%)
Reducing emissions in external projects	• Diversifying reduction methodologies – 29 in Korea and granting CDM to 211 entities • Activating external projects – Upgrading small scale projects, etc	• Activating domestic external emission projects – Promoting project discovery for each sector • Encouraging overseas reduction activities – Recognizing overseas reductions of domestic companies as domestic trades
Verification and certification of emissions	• Establishing a verification and certification system • Expanding verification experts	• Elaborating the emissions statement – Expanding the BM method • Establishing an international level of a verification system
Markets for trading allowances	• Commencing an emission permits exchange (KRX) • Implementing measures for market stabilization	• Implementing periodic auctions • Reviewing the introduction of market makers
International cooperation and industrial support	• Promoting international cooperation projects – Korea-EU cooperation project and forum between Korea, China, Japan • Financial support and tax incentives such as a reduction facility support project	• Expanding international cooperation projects – Providing Korean bilateral cooperation projects • Reinvesting allocation revenues – Reusing the revenue as eco-friendly investment funds

※ Source: The 2nd Master Plan for the Emissions Trading System, Ministry of Strategy and Finance, 2017

In 2014, the ROK established and announced the National Emission Allowance Allocation Plan for Phase I (2015-2017) of the Greenhouse-gas Emissions Trading System (the 1st Allocation Plan) pursuant to Article 2 (1)[20] of the Enforcement Decree of the Act, considering the compatibility of the first master plan with the national targets for reducing GHGs. The 1st Allocation Plan includes details such as sectors and types of businesses eligible for allocation, the total number of emission allowances, the amount allocated to each type of business, allocation standards for each

18 Grandfathering (GF): A method, based on past greenhouse gas emissions, of allocating emission allowances at or below the level of past emissions.

19 Benchmark (BM): A method of allocating emission allowances considering facility efficiency based on past activity data by business entity, such as product production

20 Article 3 (Formulation, etc. of Plans to Allocate National Emission Allowances) (1) Pursuant to Article 5 of the Act, the Minister of Environment shall establish a plan to allocate national emission allowances in consideration of conformity to targets for reducing greenhouse gases referred to in Article 42 (1) 1 of the Framework Act.... (the rest omitted)

entity, emission allowances in reserve, and offset criteria. To ensure the compatibility with the national targets for reducing GHG, the 1st Allocation Plan was developed taking into account the Roadmap to Achieve the National GHG Reduction Target (2014), which is a detailed implementation plan to achieve national GHG reduction targets[21] and sectoral reduction targets.

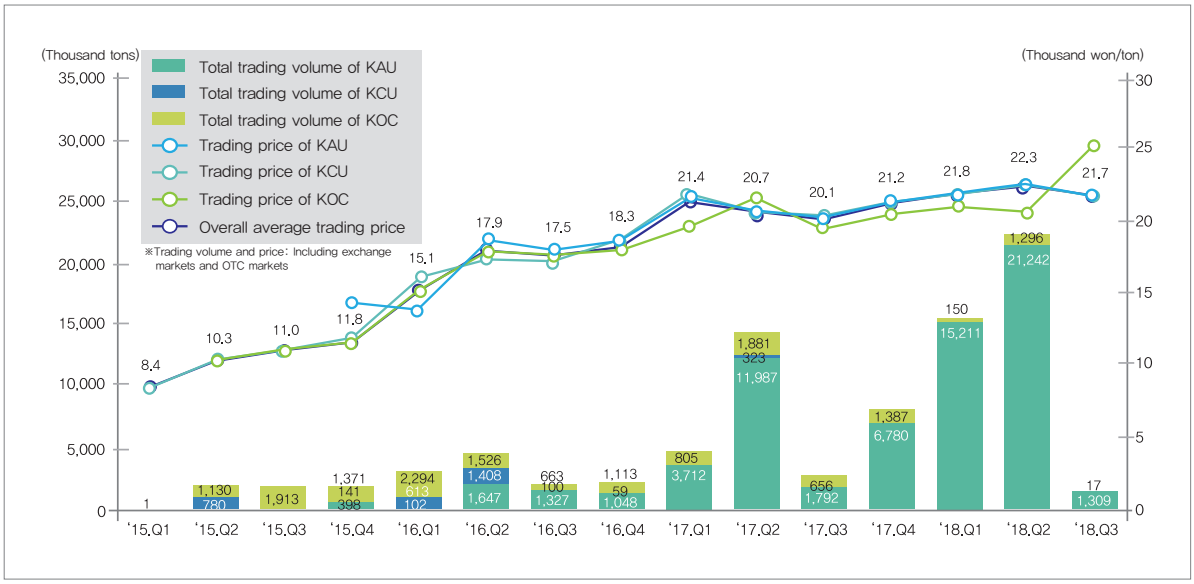
However, as the Roadmap to Achieve the National GHG Reduction Target for 2030 was announced on December 2016, changes to the allocation plan, which in principle shall be established considering the conformity to the national GHG reduction target, are inevitable. Therefore, in 2017, the ROK prepared the Changes to the National Emission Allowance Allocation Plan for the third compliance year of Phase I of the GHG Emissions Trading System (the Changes to the 1st Allocation Plan) and recalculated the total allowable emissions for the third compliance year, taking into account national GHG reduction targets and reduction measures in 2030, and adjusted the emission allowances in reserve. In addition, it separated some sub-sectors to specify allocation criteria for business entities.

The Ministry of Strategy and Finance establishes the first master plan, and the Ministry of Environment, the responsible authority, was in charge of establishing the first allocation plan, pre-allocating to companies, adjusting and canceling allocations, reporting, verification, certification, and imposing fines in 2014, one year before the introduction of the Emissions Trading System under Article 2 of the Act.

In June 2016, the operating system of the Emissions Trading System was reorganized into the system that the Ministry of Strategy and Finance supervises and the responsible ministry by sector executes. At this time, authorities for some tasks were requested and delegated to GIR. Since then, the Emissions Trading System was reorganized into the supervision of the Ministry of Environment in January 2018 and allowed the existing sectoral responsible ministries to secure their powers on national GHG reduction by maintaining the supervision function for external projects, considering the expertise of each ministry.

21 Article 25 (Establishment and Management of National Targets for Reduction of Greenhouse Gas Emissions) of the Framework Act on Low Carbon, Green Growth (1) A target for the reduction of greenhouse gas emissions referred to in Article 42 (1) 1 of the Act shall be to reduce total nationwide emissions of greenhouse gases in 2020 by 30 percent below the estimated greenhouse gas emissions in 2020.

[Figure 3-3] Price and Volume of Emission Trading System (2015-2018)



※ Source: GIR

There were initially 23 sectors subject to Phase I, but three were added for a final total of 26 sectors. The allocation method based on past emissions was applied to 20 of these sub-sectors, and three types of businesses – cement, oil refining, and airlines – were pre-allocated by applying the allocation method based on the past activity data volume (benchmark allocation method).

During Phase I, the entire emission allowances allocated to all sub-sectors were allocated for free to minimize the economic burden on business entities and to settle the system. The preliminary quota for the operation of Phase I was 1,622,600,000 KAUs, the additional quota was 43.3 million KAUs, and the revoked amount was 42 million KAUs.

Also, the Korean Credit Units, which are acquired through external reduction projects of business entities including Clean Development Mechanism (CDM) projects, are recognized, and 22.5 million Korean Offset Credits (KOCs)[22] were supplied to the market through 81 external reduction projects as of August 2018. Of all KOCs, 15.4 million tons (70%) were converted to KCUs and used for trading and submission of emission allowances.

During Phase II, the technical innovation of business entities will be induced by expanding the benchmark method, which is favorable to companies with high facility efficiency; and companies that reduce greenhouse gas emissions by investing in green facilities are given incentives[23] at the allocation. The second allowance allocation plan sets the total emission allowances of 591

22 Reductions: Reducing N_2O 9.66 million tons CO_2eq., 5.88 million tons CO_2eq. by using landfill gas, SF_6 4.57 million tons CO_2eq., 2.12 million tons CO_2eq. by using new and renewable energy, 0.21 million tons CO2eq. by fuel conversion, 0.03 million tons CO_2eq. by providing bio-energy

23 When an additional allocation is made for new or expanded facilities and when GF method is applied, reduction results are reflected.

companies at 1,777,100,000 KAUs and the additional allowances in reserve of 19 million KAUs, reflecting an increase due to the expansion of the eligible facilities and the upward revision of the emission factors compared to the first allocation plan.

In the second allocation period, among the 63 types of business, 97% of the allowances are allocated for free to 26 sub-sectors including power generation companies, and the partial onerous allocation that 3% of the allowances are being allocated at a cost through auctions, etc., is underway for the remaining 37 sub-sectors.[24] The government plans to increase the liquidity of the emission trading market and promote the activation of the emission trading market by supplying allocated emission allowances at a cost to the market through periodic auctions. In addition, the government will support the transition to a low-carbon, high-efficiency industrial structure by establishing a financial support system that reinvests the revenues of allocation auctions at a cost on industrial innovation of companies which participate in the emissions trading system.

The government also plans to build an integration platform for exchanging information that mitigates the information asymmetry problem of the participants in the emission trading market and provides trading volume and price information for the activation of the trading market. The ROK decided that it would resolve the emissions that are difficult to reduce by domestic reduction measures by using forest sinks and overseas reductions, and that the detailed plan for it would be established by reflecting the results of the follow-up negotiations of the Paris Agreement.

〈Table 3-5〉 Main Operational Directions for Phase II (2018-2020)

Descriptions	Contents
Allocation of allowances	• Leading to improve facility efficiency by expanding the benchmark method • Implementing allocation at cost (3% of the allowances allocated to the eligible business entities)
External reduction projects	• Activating domestic external emission projects • Promoting overseas reduction activities by recognizing overseas reduction results of domestic companies as domestic trades
Markets for trading allowances	• Implementing periodic auctions of allocation at a cost • Building an information integration platform for the emissions trading system
Industrial support	• Reinvesting revenues of allocation at a cost as eco-friendly investment funds

※ Source: The 2nd Master Plan for the Emissions Trading System, Ministry of Strategy and Finance, 2017

24 Eligible business entities are allocated 97% of emission allowances free of charge and 3% of emission permits are allocated at a cost.

– GHG and Energy Target Management System

Since 2010, to achieve national greenhouse gas reduction targets in accordance with the Framework Act on Low Carbon, Green Growth, the ROK has implemented a GHG and energy target management system to set and manage GHG reduction targets and energy-saving targets by designating the business entities or business places that emit and consume a certain level of GHG and energy as controlled business entities. As the emissions trading system was implemented in 2015, large business places with high GHG emissions are already using it in their operational management. Accordingly, the target management system has become a system in which small and medium-sized companies prepare for the emissions trading system before they are eligible to participate in it.

The target management system manages and supports the target implementation of controlled business entities by setting targets of GHG emissions and energy consumption. The ROK adopts a direct regulatory system in which the government establishes GHG emission targets with controlled business entities and imposes improvement orders or fines when they fail to meet the targets. The operation is divided into a supervising institution, which directs the system and performs a coordination function, and responsible ministries by sector, which set and manage the targets of controlled business entities.

The responsible ministries set annual reduction targets of controlled business entities to achieve the national GHG reduction targets, considering the new and expansion plans and reduction potentials of controlled business entities, and continue to manage the targets of GHG reduction and energy-saving by assessing implementation plans and results. The process of promoting the target management system consists of several processes—controlled business entities submit statements of greenhouse gas emissions and energy usage (in March), establish targets for the next year in consultation with the government (in September), then, establish implementation plans (in December), fulfill the targets for one year (following first year), and submit performance outputs to the government (in March of the next following year).

The controlled business entities of the target management system are divided into a company (corporation) unit and a business place unit, and the numbers subject to the application are expanding annually. For those subject to the GHG emission regulation, business entities whose annual average GHG emission and energy usage are 50,000 tons CO_2eq. or more and 200 terajoules (TJ) or more, respectively, or business places whose greenhouse gas emissions and energy usage are 15,000 tons CO_2eq. or more and 80TJ or more, respectively, are designated as controlled business entities. Under the notice of change in the criteria for controlled business entities as of 2017, there are 348 business places subject to GHG and energy target management.

In terms of responsible ministries, they are divided into 110 units for the Ministry of Land, Infrastructure and Transport, 197 units for the Ministry of Trade, Industry and Energy, 19 units for the Ministry of Agriculture, Food and Rural Affairs, 10 units for the Ministry of Oceans and Fisheries, 12 units for the Ministry of Environment, and 826 units for the public sector.

〈Table 3-6〉 Designation Criteria for Controlled Business Entities of the GHG and Energy Target Management System

Descriptions	By 2011		From 2012		From 2014	
	Business entity criteria	Business place criteria	Business entity criteria	Business place criteria	Business entity criteria	Business place criteria
Greenhouse gas ($tCO_2eq.$) Emissions	125,000	25,000	87,500	20,000	50,000	15,000
Energy (TJ) usage	500	100	350	90	200	80

※ Source: Guidelines for the Operation of the GHG and Energy Target Management System

2.2 Mitigation Policies and Actions by Sector

– Transformation Sector

The ROK confirmed the Energy Transformation Roadmap in 2017 containing the plan to phase out nuclear power plants and increase the proportion of renewable energy power generation to 30-35% by 2040 and included specific implementation plans in the 8th Master Plan for Electricity Supply and Demand (2017) and the 3rd Energy Master Plan (2019).

The Master Plan for electricity supply and demand is a 15-year long-term plan (8th planning period: 2017-2031), which is established every two years to forecast the mid- to long-term demand for electricity and accordingly, expand the power facilities. Reflecting the targets and direction of the government's energy transformation roadmap, in particular, the 8th Master Plan for Power Supply and Demand presents the key direction to promote energy promotion, such as the phase out of nuclear and coal-fired power plants and the expansion of renewable energy, a power mix centered on Environment and Safety, and a power supply and demand policy centered on demand management. Therefore, the master plan focuses on setting optimal target demands through demand management rather than promoting power plant construction first and is prioritizing eco-friendly and distributed renewable energy and LNG power generation, away from large-scale nuclear and coal-fired power generation.

In the case of coal power, the ROK plans to reduce the share of power generation, such as closing old coal power plants and in principle, limiting the entry of new coal-fired power plants into the power market, to cope with climate change and fine dust issues. While generators under construction or to be built (20 coal-fired power plants reflected in the 4th to 6th master plans for electricity supply and demand) will be built as scheduled, the power generation system with the highest efficiency level[25] (ultra-supercritical) will be introduced and built with the enhanced emission standards. In principle,

25 Power generation efficiency by system: 35-39% for sub-critical, 41% for super-critical, and 43% for ultra-supercritical

the ROK plans to limit new coal-fired power plants when establishing the master plan for electricity supply and demand, cover the growing demand for electricity with low carbon and green power sources, and also reduce the power generation of coal-fired power generators in the mid- and long-term.

In addition, the ROK presented the target to expand the share of renewable energy power generation to 30-35% by 2040, establishing the 3rd Energy Master Plan in June 2019. According to the plan, the ROK will present a plan to distribute renewable energy facilities, a target for the share of renewable energy by year, etc., in the Master Plan for Electricity Supply and Demand and the Master Plan for New and Renewable Energy, while aiming to achieve the targets by establishing the Renewable Integrated Control Management System (RMS) and expanding flexible facilities to cope with renewable energy output volatility.

In the case of new and renewable energy, the ROK implemented the Renewable Portfolio Standard (RPS) in January 2012 and has increased the annual mandatory supply rate to promote the use of renewable energy sources by power producers. The annual mandatory supply rate of renewable energy has increased gradually from 2.0% in 2012 to 5.0% in 2018 and was adjusted to 10% beyond 2023.

Since having implemented the RPS system, the amount of renewable energy generation increased from 17,346 GWh in 2011 to 46,619 GWh in 2017, and the share of renewable energy generation in total power generation increased by about 4.61 percentage points and the annual average of about 0.77 percentage points over six years. In the early stages of the 2012 RPS implementation, the implementation performance was weak compared to the targeted mandatory rate but since 2015, it has been continuously improving, exceeding 90%. To foster the domestic solar industry since 2017, support stable performance of mandatory supplies, and induce investment stabilization of photovoltaic (PV) power producers, the ROK also complementarily operates the Fixed Price Contract in the Competitive Bidding System.

〈Table 3-7〉 Status of Annual Power Generated from Renewable Energy and Total Supply Capacity of Accumulated Power Facilities

Descriptions	2013	2014	2015	2016	2017
Renewable energy power generation (GWh)	21,438	26,882	37,079	40,656	46,623
Share of total power generation (%)	3.95	4.92	6.61	7.24	8.08
Cumulative new and renewable energy total supply capacity (MW)	9,937	11,960,	13,729	13,845	15,703

※ Source: 2017 New and Renewable Energy Statistics (Ministry of Trade, Industry and Energy/Korea Energy Agency, 2018)

The ROK has carried out an integrated energy project since 1985. The integrated energy project improves energy use efficiency, leading to large energy savings and GHG reduction, provides convenience in residential and industrial sectors by integrated energy supply, and contributes to the national power supply and demand diversification by securing distributed power. Furthermore, the project contributes to mitigating the power peak load in the summer by expanding the distribution of regional air-conditioning and increases the utilization of unutilized energy, leading to improved national energy use efficiency and reduced oil dependence.

As of the end of 2017, 75 business entities supplied integrated energy at 106 business places. In the case of regional air-conditioning, the integrated energy is supplied to 2,896,000 multi-family housing units, which is equivalent to supplying regional air-conditioning to 16.9% of the[26] total 17,123,000 residential in the ROK. In the case of industries, integrated energy supplies process steam to 939 business entities. As a result, the energy supplies by integrated energy facilities reached 47,291,000 MWh as of 2017.

– Industrial Sector

To reduce the burden of declining industrial competitiveness due to GHG reduction and participate in the global low carbon economy, t industrial sector policies in responding to climate change focuses on improving energy efficiency and demand management, which enable companies to improve their competitiveness as well as reduce GHG emissions.

Legal grounds for energy demand management includes the Framework Act on Low Carbon, Green Growth, the Energy Act, the Energy Use Rationalization Act, and other statutes. The Framework Act on Low Carbon, Green Growth is the grounds for GHG reduction and the Energy Act is the grounds for the policy establishment and implementation of local governments, which are important subjects of energy demand management policy. In addition, the Energy Use Rationalization Act provides grounds for efficiency standards, information disclosure, and incentive policies in the industry, transport and equipment sectors. Also, the Energy Use Rationalization Master Plan is a representative implementation plan related to energy demand management, which mainly builds the foundation of energy use rationalization and provides contents related to energy efficiency enhancement in the industrial, transport and equipment sectors.

Above all, energy use rationalization funds, which are prepared as part of the energy use rationalization to support energy demand management policy, are used to support a part of the capital invested by companies as long-term, low-interest loans when companies invest in energy-saving facilities to save

26 Total national housing: Korean Statistical Information Service (KOSIS), 2017 Housing Census, Statistics Korea

energy and reduce GHG. The size of the energy use rationalization funds in 2015 was KRW 500 billion annually, which allocated KRW 225 billion for the investment project of enterprises specialized in energy-saving, KRW 50 billion for the investment project of target management business entities, and KRW 225 billion for the energy-saving facility installation projects.

In addition, supporting the establishment of an energy management system (EnMS) induces private companies to systematically implement energy-saving and demand management. The EnMS means the management activity scheme that energy users or energy suppliers set targets for improving energy use efficiency and systematically and continuously manage human/physical resources and management systems in accordance with certain procedures and methods. Therefore, the Korea Energy Agency supports infrastructure construction consulting, measurement infrastructure construction, monitoring system construction, etc., to encourage companies to build and use EnMS.

Meanwhile, the energy diagnosis system allows consumers to accurately grasp information about the potential for improving energy use efficiency across industries and buildings beyond providing energy efficiency information for individual equipment units. There are 627 entities subject to mandatory diagnosis, including 496 industries and 131 buildings, by which the energy used is 14,257,000 TOE in 2018. As a result of the diagnosis, the total energy-saving potential was 552,000 TOE/year, and the GHG reduction potential was 1,588 tons CO_2eq./year. Along with these, the investment required to implement the improvement plans is KRW 694.3 billion and the expected savings is KRW 296.7 billion, which can be expected to be 32.4 times the diagnostic cost when all improvement plans are fulfilled.

– Buildings Sector

The ROK enacted the Green Building Establishment Support Act in 2013 to reach the GHG reduction target in the building sector and indirectly implement efforts to expand green buildings by the Building Act and the Act on the Improvement of Urban Areas and Residential Environments. In accordance with these, the Ministry of Land, Infrastructure and Transport established the 1st Master Plan on Green Building in 2014, which contains plans to revitalize green buildings and presented strategies on the promotion of energy efficiency improvement of new buildings, inducement of energy-saving of building energy users, green building technology development, and infrastructure construction.

The ROK has established various institutional devices to quantitatively evaluate the eco-friendly efficiency of buildings and induce the activation of green buildings. While the green building certification system evaluates the degree of energy-saving and environmental pollution reduction throughout

the life cycle of buildings, the building energy efficiency rating certification system classifies energy efficiency with quantitative and objective information on the energy efficiency of buildings.

〈Table 3-8〉 Status of Green Building Certification by Year

2013	2014	2015	2016	2017
727 cases	1,034 cases	1,369 cases	1,639 cases	1,763 cases

※ Source: Korea Institute of Civil Engineering and Building Technology

The Ministry of Land, Infrastructure and Transport has been implementing the zero-energy building certification system (Zero Certification System) since January 2017. The Zero Certification System quantitatively evaluates the energy efficiency of buildings and classifies them into five classes according to the degree of zero-energy realization, which aims to reduce 5.5 million tons of CO_2eq. by 2030 in accordance with the GHG roadmap by expanding the buildings subject to the mandatory zero energy certification from public buildings of more than 10,000 ㎡ to the same size of private buildings in 2020.

The Ministry is also disseminating and expanding the building energy management system (BEMS) that monitors and controls the energy situation by connecting sensors and measurement equipment, analysis S/W, etc., by building energy sources to wired and wireless communication networks. Moreover, the Ministry revised the Regulations on Promotion of Energy Use Rationalization in Public Institutions in January 2017, making the installation of BEMS mandatory when constructing public buildings with floor areas exceeding 10,000 ㎡.

Green remodeling is a policy project to improve energy efficiency through insulation and window replacement and increase the value of existing old buildings by reducing GHG emissions. The Green Remodeling Creation Center was established to promote the project in July 2013. The public sector support project was also introduced in 2013 for the existing public buildings and provided about KRW 7 billion to 107 places by 2018. The private sector interest support project provides up to 3% interest for five years when borrowing for construction costs to improve the energy efficiency of old buildings.

〈Table 3-9〉 Major Results of Green Remodeling Projects

Descriptions		2014	2015	2016	2017	Total
Projects	No. of cases	352	2,753	7,742	8,551	19,398
	Amount (million KRW)	55,702	36,483	75,949	95,763	263,897

※ Source: Green Remodeling Creation Center Website

– Transportation Sector

The transportation sector sought to transform the existing transportation logistics system into an environment-friendly and energy-saving low carbon transportation logistics system in preparation for changes in circumstances of the transportation logistics system, such as climate change, energy crisis, and environmental protection, based on the Sustainable Transportation Logistics Development Act enacted in December 2009. Accordingly, the 1st Sustainable National Transportation Logistics Development Master Plan (2011) is a master plan for GHG reduction in the transportation sector, which establishes mid- and long-term policy targets and strategies to systematically promote transportation and logistics policies and provides a comprehensive overview of the development of sustainable transportation logistics which was fragmented in several laws.

Greenhouse Gas Reduction Policies and Means in the Transport Sector are largely divided into roads, shipping, railway and aviation sectors and recently, fine dust reduction as well as greenhouse gas reduction are being considered.

In addition, the Passenger Cars Average Fuel Efficiency System manages the average fuel efficiency of passenger cars sold yearly by vehicle manufacturers in the ROK, which reduces GHG emissions through tire efficiency rating system and lightweight vehicle, etc., to improve fuel economy. The system establishes average fuel efficiency targets by 2020 so that the average fuel economy reaches the level of developed countries and plans to expand vehicles subject to the average fuel consumption regulation in the future. As of 2016, 1,788 models of vehicles registered for fuel efficiency have been registered and managed.

〈Table 3-10〉 Fuel Efficiency Standards by Year

Descriptions	2016	2017	2018	2019	2020
Fuel efficiency (km/l)	18.60	19.20	19.60	21.40	24.30
GHG (g/km)	127.00	123.00	120.00	110.00	97.00

※ Source: Vehicle Average Greenhouse Gas Emission and Fuel Efficiency Standards for the Next Period (2016-2020), Ministry of Environment, 2014

The road sector focuses on improving the fuel efficiency of internal combustion engine vehicles as well as the distribution of environment-friendly vehicles. In the case of the distribution of environment-friendly cars, the Master Plan for Development and Distribution of Environment-Friendly Vehicles is established on a five-year basis in accordance with the Act on Promotion of Development and Distribution of Environment-Friendly Motor Vehicles, and the expansion of environment-friendly vehicles is promoted by providing subsidies, developing and distributing high efficiency and low-cost

hybrid vehicles (HYB), improving the performance of electric vehicles (EV) and expanding charging facilities, diversifying charging forms, improving durability and stability of fuel cell electric vehicles (FCEV), and conducting demonstration projects.

〈Table 3-11〉 Eco-friendly Vehicles Distribution Plan

Descriptions		2017	2020	2022
Eco-friendly vehicles (accumulated)	Total	250,000 units	1,500,000 units	2,000,000 units
	EVs	12,000 units	250,000 units	350,000 units
	FCEVs	100 units	10,000 units	15,000 units
	HYBs	238,000 units	1,240,000 units	1,635,000 units
Charging infrastructure (accumulated)	Total	764 units	3,100 units	10,310 units
	Electricity (rapid)	750 units	3,000 units	10,000 units
	Hydrogen	14 places	100 places	310 places

※ Source: Comprehensive Set of Measures for Fine Dust Control, Jointly Report by relevant Ministries, 2017

Also, the Renewable Fuel Standard (RFS) mandates that the fuel for transportation (diesel) should be supplied being mixed with a certain ratio or more of renewable fuel (biodiesel). Accordingly, the mixed-use at a 0.5% rate began in 2007, which was mandated at 2% in 2010 and then, increased to 3% in 2018. Biodiesel is mainly made from recycled used cooking oil, of which 152,000 tons were recycled, saving KRW 259.2 billion in the treatment cost of pollutants as of 2016.

The shipping sector reduces GHG emissions by improving energy efficiency by introducing fuel-efficient linear technology, high-efficiency propellers, gas engines, and electric propulsion systems and supplying environment-friendly ships. For these purposes, the government has supported ocean-going vessels to be replaced with eco-friendly vessels since 2018 and plans to induce the transition of coastal vessels to eco-friendly vessels by interest subsidy and fund support for the modernization of coastal vessels. Since the International Maritime Organization (IMO) plans to regulate the SOx content of ship fuel oil from 3.5% to 0.5% by 2020 and environmental regulations for NOx also are enhanced, the government responds to the environmental regulations by expanding the use of AMPs and introducing LNG propulsion ships by establishing the Green Port Construction General Plan.

In the air transportation sector, the government has concluded the Agreement on Voluntary Greenhouse Gas Reduction in Aviation[27] with the national flag airlines and responded to climate change and GHG emission regulations since 2010. By the action, about 450,000 tons CO_2eq. have been reduced as of 2017. Based on these airlines' know-how, GHG emissions

27 Airlines for domestic air routes are subject to the national emissions trading system in accordance with the Act on the Allocation and Trading of Greenhouse-Gas Emission Permits, and airlines for international air routes voluntarily participate in the Agreement.

are reduced with 1.3% of fuel efficiency improvement rate every year by discovering additional reduction measures and improving air traffic control and airport operations.

In addition, the transportation sector also extends and expands BRT and operates transit centers and restricted public transportation districts to increase the share of public transportation and also, increases the share of railway transportation by expanding urban/metropolitan railway network and expanding national high-speed railway operations. Also, the combined inter-modal transportation system was strengthened by the modal shift project, which shifts road freight into rail and coastal shipping, and GHG emissions were reduced by 945,000 tons CO_2eq. were reduced as of 2018 by improving railway transportation operation efficiency and transportation capacity.

As part of the traffic demand management by policies to restrict passenger cars, such as walking and using bicycles, expanding telework, and activating economic driving, this sector develops and implements the Action Plan for the Vitalization of Non-Powered and Carbon-Free Means of Transportation to vitalize walking and bicycle use in 2011. In addition, the sector established a safe and convenient base for bicycle use, such as connecting walking measures and bicycles and connecting public transportation and bicycles. The sector also induces energy savings and GHG reduction by the operation of an eco-drive training program to improve drivers' economic driving practice rate and the expansion of educational systems.

– Waste Sector

The ROK's targets for waste policies have been developed from safe waste treatment to recycling waste and then to resource circulation. The Waste Control Act was enacted in 1986 to unify the waste management system, which had been divided by the Natural Environment Conservation Act and the Filth Cleaning Act. Also, the Act on the Promotion of Saving and Recycling of Resources was enacted in 1992, shifting from conventional waste control policies to reduction and recycling of waste, and as the Act was revised in 2008, the concept of resource circulation was introduced as the direction of waste control policy shifted from simple recycling-centered policy to occurrence suppression and recycling expansion.

In 2018, the Ministry of Environment established the 1st Resource Circulation Action Plan (2018-2027) as a blueprint for transforming the ROK's economic and social structure into a resource circulation scheme. The Action Plan is a national strategy for every 10 years (2018-2027) on the efficient use of resources, the suppression of waste generation and the promotion of circulation, which was established based on the Framework Act on Resource Circulation which was implemented from January 2018. The resource

circulation policy is divided into three aspects: ① reduction and reuse, ② recycling, and ③ energy recovery.

Reduction and reuse policies include restrictions of disposable products, regulations against over-packaging, volume-based waste fee system, business place waste reduction systems, and deposit return scheme. The Business place waste reduction system fundamentally suppresses waste generation from the product production stage as well as the product distribution and consumption stage, which introduced the Resources Circulation Performance Management System to establish a virtuous cycle of resources in 2018.

Also, recycling policies have introduced various advanced systems such as waste charges, mandatory separate discharge, extended producer responsibility (EPR), and environmental assessment for recycling waste, to promote the recycling of waste.

The energy recovery policy focuses on energy recovery of waste resources, such as using organic waste resources as energy and establishing solid refuse fuel (SRF) and environment-friendly energy towns. In other words, the policy essentially prioritizes the recycling of materials, taking into account the priority of waste treatment (reduction〉 reuse〉 recycling〉 energy recovery) and then, promotes energy recovery.

The Ministry of Environment established the 4th National General Environment Plan (2016-2035) in December 2015 and selected key indicators after setting the national mid- to long-term resource circulation targets by stage to restrict the generation of waste and promote circulation.

〈Table 3-12〉 Key Indicators of Low-carbon and Resource Circulation in the 4th National General Environmental Plan

Key Indicators	Unit	2015	2025	2035
GHG emissions	$tCO_2eq.$	688 million tons (as of 2012)	–	536 million tons (as of 2030)
Resource productivity	KRW/kg	1,382 (as of 2014)	2,000	3,500
Recycling rate (recycling capacity/domestic waste generation)	%	83.2 (as of 2013)	91.0	97.0
Landfill rate	%	9.6	2.5	1.0
Share of environmental industry (to GDP)	%	6.6 (as of 2013)	8	10

※Source: 4th National General Environment Plan, Ministry of Environment, 2015

– Public and Other Sectors

The ROK is implementing the public sector GHG and energy target management system for 826 institutions in the public sector (as of 2017) including central administrative agencies, local governments, public institutions, and national universities. The first period (2011–2015) aims to reduce 20% of baseline emissions by 2015, and the second period (2016–2020) aims to reduce them by 30% by 2020. The public sector reduction targets were set in consideration of the 2020 national greenhouse gas reduction target, public sector reduction target and emission forecasts announced in 2009, which were higher than others in the public sector to set a good example.

The Ministry of Environment has been providing financial support (government subsidy of 50%) to the project since 2012, such as establishment of a greenhouse gas reduction monitoring system, to achieve the greenhouse gas reduction target of the public sector, and links its GHG reduction performance with an external valuation system to increase public sector reduction rates. The valuation is implemented, that is, public institutions are evaluated by the Ministry of Strategy and Finance, and local governments and local public enterprises by the Ministry of the Interior and Safety. As a result, the reduction rate was 18.3% in 2017, increased by 12.5% from the beginning (2011) of the system, and emissions were reduced by 12% compared with 2011.

〈Table 3–13〉 Operational Results of the Public Sector of the GHG and Energy Target Management System

Descriptions	2011	2012	2013	2014	2015	2016	2017
eline emissions (Thousand tons CO_2eq.)	5,024	4,888	4,541	4,890	4,761	4,990	4,985
Yearly emissions (Thousand tons CO_2eq.)	4,734	4,492	4,093	4,152	3,935	4,204	4,172
Yearly reduction rate (%)	5.8	8.1	9.9	15.1	17.5	16.0	18.3

※ Source: Presentation Material on 2017 Public Sector Greenhouse Gas and Energy Target Management Operational Performance Report Contest, Ministry of Environment, 2018

– Agricultural and Livestock Sector

The ROK has finalized and announced the Action Plan for Climate Change in Agriculture, Fishery, and Foods (2011–2020) to proactively respond to climate change in agriculture, fisheries, and foods sectors in November 2011. The detailed plan is implemented to disseminate low carbon farming and energy-saving facilities and expand renewable energy facilities to reduce GHG emissions in the agriculture sector. It also continues to expand livestock manure resources and energy facilities in the livestock sector and pursue measures to reduce GHG caused by the enteric fermentation of ruminants by supplying low-methane feed and high-quality coarse feed. Also, there are, as greenhouse gas reduction projects in the agricultural industry, the agriculture and rural voluntary greenhouse gas reduction project that directly

reduces GHG emissions from agricultural production sites and the low carbon agricultural products certification system to reduce GHG in terms of distribution and consumption.

The agriculture and rural voluntary greenhouse gas reduction project, implemented since 2012, acts as a carbon offset system, which encourages farmers to reduce GHG emissions based on economic incentives. Currently, the project provides incentives of KRW 10,000 per ton CO_2eq. for the reduced GHG emissions, and those subject to the project include agriculture and forest cooperatives, industry and academia institutes, and agricultural organizations including farms, cooperative units, and farming association corporations.

Representative GHG reduction low-carbon agricultural technologies are biogas plants and geothermal energy; 10,111 tons CO_2eq. and 4,959 tons CO_2eq. of GHG emissions were reduced by using biogas plants and geothermal energy, respectively, as of 2017.

The low carbon agricultural products certification system is a national certification system where low-carbon agricultural technologies are applied to the agricultural products that have received the Good Agricultural Practices (GAP) certification. As part of the Action Plan for Climate Change in Agriculture, Fishery, and Foods, a pilot project was launched in 2012 and in parallel, the awarding of the certification was implemented in 2014. Beginning with the certification of seven agricultural management bodies (60 farms) in 2012, 478 agricultural management bodies (2,763 farms) have been certified as of December 2017. The key points of the low carbon agricultural products certification system are to minimize the environmental load on climate change and build an efficient agricultural production system by quantitatively managing and verifying various farming materials put into production and by inducing the production to meet the certification criteria.

– Forest Sector

The ROK enacted the Forest Act in 1961, rapidly moved forward to reforestation in accordance with the national forest development plan in 1960's to 1970's and has been promoting forest projects by establishing the forest basic plan since 1973. Meanwhile, the national forest carbon removal is expected to be about 22 million tons CO_2eq. by 2030 under the domestic sustainable forest management policy.

〈Table 3-14〉 Status of Forest Carbon Removal

(Unit: Thousand tons CO_2eq.)

Descriptions	2017	2018	2019	2020	2025	2030
Removal	42,050	39,279	37,544	35,773	28,673	22,246

※ Source: The 2nd Forest Carbon Sink Enhancement Plan, Korea Forest Service, 2018

The sector enacted the Act on the Management and Improvement of Carbon Sink in 2013 and in the same year, notified the Social Contribution Forest Carbon Offset Management Standard to promote voluntary forest carbon sink. Thus, the social contribution forest carbon offset system has been implemented since 2013. The Korea Forest Service is making efforts to increase domestic forest carbon sinks by establishing the Forest Carbon Sink Enhancement Plan, Forest Basic Plan, etc. Moreover, to get the maximum recognition of domestic forest carbon removal, the Korea Forest Service is conducting research and advancement of forest inventory to set the forest management baseline as zero in the international community and pilot projects for Reducing Emissions from Deforestation and Forest Degradation (REDD+) in developing countries such as Cambodia and Indonesia.

The forest carbon offset system specifies that the Korea Forest Service certifies removal to business entities that voluntarily perform forest carbon offset activities, which provide information on the types of projects for forest carbon offsets and assists business entities in carrying out administrative procedures to activate the forest carbon offset system. As of 2017, 157 projects were registered for the forest carbon offset system, and the annual estimated forest carbon removal accounted for 119,000 tons CO_2eq.

[Sacred Bell of Great King Seongdeok]
Great cultural heritage created through merging the religion, science, and art of unified Silla

CHAPTER 4

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Climate Change Impacts and Adaptation Measures

1. Climate Change Status and Projections
2. Climate Change Impacts and Vulnerability Assessment
3. Adaptation Measures

1. Climate Change Status and Projections

1.1 Climate Change Status

The trend of climate change in the ROK showed a change rate of 0.41℃/10 years during 1981–2010 and 0.5℃/10 years during 2001–2010. This is a greater variation than the change rate of +0.23℃/10 years from 1954–1999.

There is considerable fluctuation in the average annual precipitation in the ROK, but recent trends are for increasing amounts. In particular, the average annual precipitation during the last 10 years (2001–2010) was 1,412mm, an increase of 7.4% over the last 30 years. The increase in annual precipitation in the ROK over the past 10 years is attributed to the lengthening summer season where the largest share of precipitation occurs.

The distribution of annual precipitation is complex and varies greatly by region depending on the topography and type of precipitation. The annual precipitation tends to decrease as the latitude increases, and thus the precipitation on the southern coast is the highest in the ROK. Heat waves are most common in areas with high temperatures in the daytime. The heatwave days in Daegu were the longest (23.2 days) in the ROK and were observed in the inland areas of Jeolla-do and Gyeongsang-do at 16–23 days per year. Tropical nights are also common in areas with high temperatures at night. The maximum number of tropical nights is 25.4 days at Seogwipo in the ROK and 11.8 days at Pohang on the mainland. The spatial distribution of heavy rain days is similar to that of annual precipitation. This reflects the tendency of summer rainy season and localized heavy rain to move from east to west, and heavy rain days occur when the ROK is in the path of seasonal rain fronts and typhoons during summer.

The average annual temperature in the ROK is 12.5℃, and the average temperatures by season are 23.6℃ during summer, 14.1℃ during autumn, 11.7℃ during spring, and 0.6℃ during winter. The annual average daily temperature range of the ROK's climate is 10.4℃, with the largest daily temperature range in spring (11.9℃) and the smallest in summer (8.7℃). Annual precipitation is 1,307.7㎜ and summer precipitation accounts for 55.3%. With respect to seasonal precipitation, summer (723.2 mm) records the highest amount, followed by autumn (259.7 mm), spring (236.6 mm), and winter (88.5 mm). There are large seasonal differences because precipitation in winter only accounts for 6.8%. Surface wind speed in the ROK is about 1.8–2.3㎧, which is a little stronger than the average annual wind speed of 2.0㎧ (7.2km/h). The relative humidity is around 68.6% year-round, highest at 77.0% in summer, and low in spring (63.2%) and winter (63.5%).

〈Table 4-1〉 Average Normal of Annual and Seasonal Climate Factors in the ROK (as of 1981-2010)

Descriptions	Annual average	Spring	Summer	Autumn	Winter
Mean temperature (℃)	12.5	11.7	23.6	14.1	0.6
Daily highest temperature (℃)	18.1	17.9	28.4	20.1	6.1
Daily lowest temperature (℃)	7.7	6.0	19.7	9.2	-4.1
Precipitation (㎜)	1,307.7	236.6	723.2	259.7	88.5
Wind speed (㎧)	2.0	2.3	1.8	1.8	2.2
Relative humidity (%)	68.6	63.2	77.0	70.9	63.5

※ Source: Climate Change Forecast Report on the Korean Peninsula, Korea Meteorological Administration, 2018

1.2 Climate Change Projections

The impact of climate change in the ROK is detected in a wide range of sectors including weather, ecology, environment, and water resources and regionally occurring in a different pattern. Therefore, future climate change trends in the ROK are also expected to occur regionally in a different pattern. To prepare for and cope with large-scale natural disasters caused by climate change, it is important to use systematic and scientific climate forecast information.

Based on the Representative Concentration Pathways (RCP) 8.5 scenario where GHG emissions occur with current trends (without reduction), the average temperature and precipitation in the ROK will rise by 4.4℃ and by 172.5mm respectively in the half of this century (2071-2100). Spring and summer are arriving sooner and autumn and winter are starting later because of climate change. As a result, the days of heat waves and summer increased to 25.4 and 66.2 days, respectively. On the other hand, the days of cold waves and freezing decreased to 6.2 days and 8.9 days, respectively.

〈Table 4-2〉 Future Projections of the ROK by Scenario (RCP2.6/4.5/6.0/8.5)

Climate Factors	RCP Scenario	Current Climate Value(1981-2010)	Early part of the centur (2021-2040)	Middle part of the century(2041-2070)	Later part of the century(2071-2100)
Mean temperature (℃)	2.6	12.5	13.9	14.2	14.2
	4.5		13.7	14.6	15.1
	6.0		13.2	13.9	15.2
	8.5		13.6	15.0	16.9
Highest Temperature (℃)	2.6	18.1	19.4	19.7	19.7
	4.5		19.5	20.2	20.8
	6.0		18.8	19.5	20.8
	8.5		19.2	20.6	22.6
Lowest Temperature (℃)	2.6	7.7	9.2	9.4	9.4
	4.5		8.8	9.9	10.3
	6.0		8.5	9.1	10.5
	8.5		8.8	10.2	12.0
Precipitation (㎜)	2.6	1,307.7	1,416.8	1,397.1	1,393.9
	4.5		1,271.2	1,472.8	1,395.3
	6.0		1,346.0	1,327.7	1,456.9
	8.5		1,348.3	1,366.4	1,480.2
Days of heat waves	2.6	10.1	11.2	13.4	12.7
	4.5		14.5	14.7	19.0
	6.0		11.1	15.5	20.8
	8.5		12.3	21.4	35.5

※ Source: Climate Change Forecast Report on the Korean Peninsula, Korea Meteorological Administration, 2018

2. Climate Change Impacts and Vulnerability Assessment

2.1 Vulnerability Assessment

The ROK discussed climate change adaptation in earnest as it enacted the Framework Act on Low Carbon, Green Growth and its Enforcement Decree in 2010, and the national adaptation effort is specifically implemented based on the 2nd National Climate Change Adaptation Measures established in 2015. Accordingly, climate change vulnerability assessment and risk management have been established as the key projects of the policy, "establishing a scientific climate change risk management system," among execution plans for key projects for each policy direction of the 2nd National Climate Change Adaptation Measures (2015).

To establish adaptation measures to climate change, a vulnerability assessment of the vulnerability to disasters caused by abnormal weather (drought, floods, heat waves, etc.) must be preceded. Vulnerability assessment determines the degree of susceptibility to damage sustained by climate change and the extent to which a system (spatial units, including basic and municipal governments) cannot cope with the adverse effects of climate change and is used as an integrated concept of climate exposure, sensitivity, and adaptability.

VESTAP[28] is a climate change vulnerability assessment tool system for supporting the establishment of adaptation measures, which is produced as a web-based service. Users can conduct climate change vulnerability assessments in each region through 32 vulnerability assessment items in seven categories offered by VESTAP, and then if additional vulnerability assessment items suitable for the situation of the evaluation target are needed, they can create and use vulnerability assessment items for each environment.

〈Table 4-3〉 VESTAP Vulnerability Assessment Items List

Sector	Vulnerability assessment Items	Sector	Vulnerability assessment Items
Health (9)	Health vulnerability by flood	Marine/ Fishery(1)	Vulnerability of the fishing industry (aquaculture industry) by changes in water temperature
	Health vulnerability by typhoons	Disaster (4)	Infrastructure vulnerability by flood
	Health vulnerability by heat waves		Infrastructure vulnerability by hot waves
	Health vulnerability by cold waves		Infrastructure vulnerability by heavy snows
	Health vulnerability by the rise of ozone concentration		Infrastructure vulnerability by setup
	Health vulnerability by fine dust	Agriculture (5)	Vulnerability of cropland soil erosion
	Health vulnerability by other air pollutants		Vulnerability of cultivation/breeding facilities
	Epidemic vulnerability by insects and rodents		Vulnerability of rice productivity
	Health vulnerability by waterborne mediated diseases		Vulnerability of apple productivity
Forestry (7)	Landslide due to heavy rain		Vulnerability of livestock productivity
	Vulnerability of forest road by landslides	Water management (3)	Vulnerability of flood control
	Vulnerability by wildfire		Vulnerability of irrigation
	Pine trees' vulnerability by pests		Vulnerability of water quality and aquatic ecology
	Vulnerability of pine trees and matsutakes	Ecology (3)	Vulnerability of needle leaf trees
	Vulnerability of forest productivity		Insects' vulnerability
	Vulnerability of forest vegetation by drought		Vulnerability of needle leaf trees

※ Source: VESTAP

28 VESTAP (Vulnerability Assessment Tool to build a Climate Change Adaptation Plan): A vulnerability assessment program

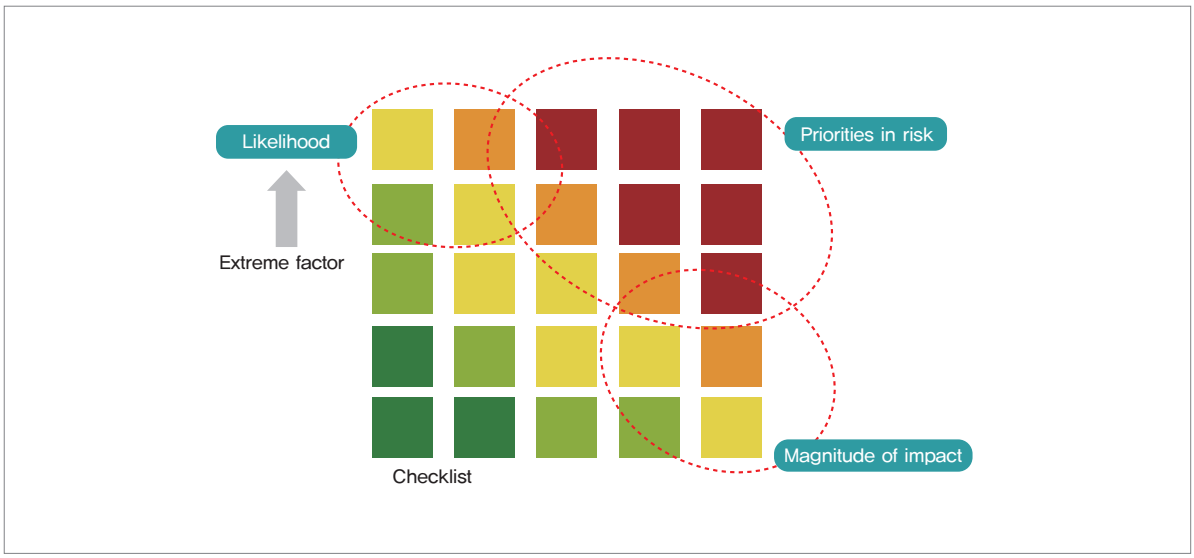
2.2 Risk Assessment

Climate change risk assessment aims to reduce uncertainty about the impacts of climate change and aids in establishing climate change response policies. Because climate change risks can vary not only from country to country but also from individual characteristics of a certain region in the same country, risk assessment considering the characteristics of the region must be carried out.

The primary purpose of risk assessment is to reduce future uncertainty about climate change impacts, and since relative impact and risk priorities are derived based on this, in recent years risk assessment has become a tool for establishing and adapting strategies and policies to climate change.

Climate change risk can be calculated by multiplying the magnitude of impact by the likelihood of a climate impact factor. The climate impact factor is the likelihood of extreme weather such as heat and cold waves, heavy rain, etc., and the magnitude of impact represents the degree of the impact on the infrastructure due to climate change. Therefore, risk assessment can provide a first priority response to climate change risks that are likely to occur and their impact.

[Figure 4-1] Climate Change Risk Assessment



※ Source: National Climate Change Adaptation Center

In the ROK, the Ministry of Environment and the National Climate Change Adaptation Center of the Korea Environment Institute, Corporate Climate Change Adaptation Plan estimates the damage to private companies caused by climate change and operates the Climate change Risk Assessment System (CRAS) to allow companies to voluntarily establish climate change adaptation plans and reflect them in their management plans and strategies.

The CRAS is a tool that assists companies in establishing adaptation plans to voluntarily and proactively respond and cope with climate change risks.

In other words, the system can find potential risks to companies that may arise from climate change, identify the risk management level and priorities through analysis and assessment processes, and preemptively diagnose the impact of climate change. The CRAS system has been used to support 60 companies and institutions to establish climate change adaptation plans and educate their employees on climate change adaptation.

3. Adaptation Measures

3.1 Institutional Foundation

To reduce the impact of climate change, the ROK should make efforts first of all for preventive management. The ROK, therefore, has made it mandatory to establish and implement measures to adapt to climate change at national and local government levels in accordance with the Framework Act on Low Carbon, Green Growth and its Enforcement Decree, which contain provisions on the establishment and implementation of adaptation measures to mitigate climate change impact or respond to health and natural disasters, etc. At present, the ROK strives to minimize the impacts of climate change and protect the safety and property of its people by establishing the National Climate Change Adaptation General Plan, National Climate Change Adaptation Measures, and Climate Change Response Master Plan. In addition, at the local government level, Metropolitan Cities/Dos/Sis/Guns are establishing their own measures to adapt to climate change and implementing detailed plans, including the Daegu International Heat Wave Response Forum and the campaign of Ten Million Trees.

〈Table 4-4〉 Climate Change Adaptation Measures History

Descriptions	Items	Contents
National climate change adaptation measures	2nd National Climate Change Adaptation Measures (December 2015)	• (System) Four policy sectors and one policy foundation • (Characteristics) Strengthening linkage and integration by sector through scientific analysis
	Climate Change Response Master Plan (December 2016)	• (System) Seven areas and 18 projects • (Characteristics) 1st master plan that includes reductions, adaptation to climate change, and international cooperation
Local governments' change adaptation measures	Local (municipal and basic) governments	• Establishment and implementation of detailed execution plan for measures to adapt to climate change in accordance with the Framework Act on Low Carbon, • Green Growth (Article 48 (4)) and the Enforcement Decree of the Act (Article 38 (2))
	Climate change adaptation measures of Metropolitan Cities and Dos.	• Completed in 2014, the 1st Climate Change Adaptation Measures in 17 Metropolitan Cities and Dos for the years of 2012 to 2016
	onwide basic Sis/Guns/Gus	• 226 nationwide basic Sis/Guns/Gus established and implemented detailed execution plans of the 1st Climate Change Adaptation Measures (2012-2015)

3.2 Institutional Measures

– National Climate Change Adaptation General Plan

The National Climate Change Adaptation General Plan is Korea's first national climate change adaptation plan, which is the national master plan established in 2008 to present the vision and direction of national adaptation policy. The National Climate Change Adaptation General Plan established the vision of "building a safe society and supporting green growth through climate change adaptation" and divided the planning period into short-term and long-term targets so that climate change adaptation measures can be established in climate change monitoring and forecasting, impact and vulnerability assessment, and adaptation projects, during the planning period spanning 22 years from 2009 to 2030.

〈Table 4-5〉 Periodic Targets in the National Climate Change Adaptation General Plan

Descriptions	Period	Contents
Short-term target	2009-2012	• Strengthening comprehensive and systematic climate change adaptation capacity – Preparing 100% map of ROK's space and temporal vulnerability – Achieving 70% of predicted and monitored technology level compared with advanced countries
Long-term target	2013-2030	• Reducing climate change risks and realizing opportunities – 10% decrease in weather disasters compared to the past 10 years (1996-2005) – Achieving 1% of GDP for production related to climate change adaptation

The National Climate Change Adaptation General Plan divided the key execution area into three categories—establishment of a climate change risk assessment system, implementation of climate change adaptation programs by sub-sector, and securement of domestic and international cooperation and institutional foundation, and set detailed key projects for each sector.

To achieve the targets, the Plan established the five promotion strategies of ① establishing a scientific and comprehensive climate change risk assessment system, ② providing cost-effective and sustainable adaptation programs, ③ establishing domestic partnerships to strengthen adaptive capacity and raising awareness, ④ securing global leadership through international cooperation and contributions, ⑤ securing institutional foundation for reinforcement of adaptive actions.

– National Climate Change Adaptation Measures

The National Climate Change Adaptation Measures are the first statutory plan with regard to climate change adaptation established by supplementing and improving the contents of the National Climate Change Adaptation General Plan established in 2008 under the Framework Act on Low Carbon, Green Growth. These adaptation measures are established as five-year rolling plans in consideration of the uncertainty of climate change impacts, and the 1st National Climate Change Adaptation Measures (2011-2015) were established and implemented in 2010. The 2nd National Climate Change Adaptation Measures (2016-2020) was established and is being implemented

to respond to climate and socio-economic changes and domestic and international policy demands.

The ROK not only presented the basic system of detailed implementation plans of climate change adaptation measures through the 1st National Climate Change Adaptation Measures but also assisted local governments in establishing climate change adaptation measures by establishing and implementing detailed implementation plans for climate change adaptation measures. Through these, a detailed implementation plan for climate change adaptation measures for nationwide 17 Metropolitan Cities/Dos and 226 basic Sis/Guns/Gus were established, and an implementation system for climate change adaption measures, ranging from the nation to municipal and basic governments were provided.

However, the 1st Adaptation Measures have limitations that the strategic foundation system to promote climate change adaptation is weak, such as the absence of mid- and long-term targets and performance indicators by sector, the absence of a policy feedback process leading to monitoring, evaluation, and correction/completion of implementation, and the lack of linkage between related projects and overlap problems due to individual project discovery and execution carried out by individual sectors and departments.

The 2nd National Climate Change Adaptation Measures were jointly established by 20 ministries to carry out the national tasks to strengthen the adaptability to climate change. After the 1st National Climate Change Adaptation Measures, the 2nd National Climate Change Adaptation Measures, which are planned for 2016-2020. consists of 5 major adaptation principles, 4 sectors, 1 foundation, and 20 major tasks under the vision of "building a happy and safe society for climate change adaptation."

To strengthen the system for adapting to climate change, the 2nd National Climate Change Adaptation Measures promoted the formation and operation of the relevant ministries council composed of 20 directors of government ministries on national climate change adaptation measures and the climate change adaptation working council. Also, the 2nd Adaptation Measures revised laws and regulations related to climate change adaptation and revitalized the National Climate Change Adaptation Center.

– Climate Change Response Master Plan

The Climate Change Response Master Plan is the master plan for response to climate change, which is established and implemented every five years for a period of 20 years under Article 40 of the Framework Act on Low Carbon, Green Growth. The 1st Climate Change Response Master Plan was established in accordance with Basic Principles for Coping with Climate

Change[29] with a planning period of 2017–2036. The Master Plan presented the vision of "realizing a low carbon society through efficient climate change response" and to accomplish this, 18 detailed execution tasks were selected from seven areas.

Unlike the existing related plans that focused solely on realizing reduction policies, the 1st Climate Change Response Master Plan is the first comprehensive plan that encompasses reduction, climate change adaptation, and international cooperation, etc. In particular, apart from establishing a plan to implement GHG reduction by existing government-led top-down methods, the 1st Master Plan reflected the bottom-up GHG reduction implementation plan with the participation of policy consumers such as industries and associations for the first time to achieve the ROK's 2030 reduction target under the new climate scheme. It also includes adaptation measures to mitigate climate change risks and impacts and respond to health and natural disasters. It not only expressed its willingness to create a low carbon society but also strengthened cooperation with the international community by actively participating in the international community's efforts to respond to climate change through the climate change response plan.

In addition, to transit to a new growth paradigm in response to the new climate scheme, the ROK established the Climate Change Response Master Plan, including ① transition from energy-consuming economic structure to low-carbon economic system, ② transition to a virtuous cycle in response to climate change, ③ emphasis on the importance of climate change adaptation in GHG reduction, and begun to transform existing energy and climate change response policies. Also, the Climate Change Response Master Plan is to prepare for low-carbon implementation by the 30-year national GHG reduction target, implementation of climate change adaptation measures, etc.

29 Basic Principles for Coping with Climate Change: Actively participating in global efforts to respond to climate change, achieving GHG reduction through the use of regulations, markets and technologies, and minimizing the impact of climate change (Article 38 of the Framework Act on Low Carbon, Green Growth)

[Jikji Simche Yojeol (Anthology of Great Buddhist Priests' Zen Teachings)]
World's oldest movable metal type-printed book in Koryo Dynasty

CHAPTER 5

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Research and Systematic Observation

1. Research and Technology Development
2. Systematic Observation

1. Research and Technology Development

1.1 Roadmap for Securing Technology for Climate Change Response and Clean Energy Technology Development Strategy

In 2015, all countries of the world submitted the Intended Nationally Determined Contributions (INDCs) through the Paris Agreement to prevent global warming and agreed to submit raised targets every five years. To achieve the targets, it is necessary to research and develop green technologies continuously to minimize GHG and pollutant emissions and climate technologies to cope with climate change. Moreover, to accurately predict and systematically respond to future climate change such as setting realistic and objective regulatory targets of international agreements, it is very important to have scientific evidence on the global atmospheric composition. Currently, more than 800 observatories are registered and operated in the Global Atmosphere Watch (GAW)[30] observation system in more than 100 countries among the members of the World Meteorological Organization (WMO), and the ROK has installed and operates 13 observatories as the global atmosphere monitoring network for the Korean Peninsula.

On January 2009, when the Executive Committee of the National Ministry of Science and Technology has finalized the Comprehensive Set of Measures for Green Technology Research and Development for low carbon, green growth, the ROK selected 27 key green technologies from 75 candidate technologies derived by expert groups and the Green Technology Council among the key technologies to be supported. The selection criteria for the technologies have considered the weight of technology capability and investment priority by technology along with the adjustment of strategic importance based on three main factors: contribution to economic growth, contribution to environmental sustainability, and strategic importance.

For five categories in two areas of the detailed key technologies and five categories and 15 sub-categories in 27 key green technologies, the classification and name of some technical groups are changed, such as the Core Technology Development Strategy for Climate Change Response (2014), Revitalization of New Energy Industry and Implementation of Core Technology Development Strategy for Climate Change Response (2015), and Carbon Resources Development Strategy (2016). Therefore, the classification of detailed technologies was redefined, and the top 10 green and climate technologies and the Clean Energy Technology Developmental Strategy for Climate Change Response and New Industry Creation (2016) were finally derived for the Climate Technology Roadmap (CTR) (2016).

The biggest difference between the top 10 green and climate technologies and the existing classification system is that the system of five categories and 30 sub-categories in two areas of detailed climate change response key technologies, and the five categories and 15 sub-category system in 27

30 GAW (Global Atmosphere Watch): Global atmosphere monitoring program

key green technologies has been changed into the top 10 major technology system in three areas. In particular, the existing classification of climate change response technologies and the sub-categories in the 27 key green technologies are excluded or changed and are condensed to 10 key technologies: solar cells, fuel cells, biofuels, secondary cells, power IT, carbon capture and storage (CCS), by-product gas conversion, CO_2 conversion, CO_2 mineralization, and common platform.

Under the vision of transforming the new climate crisis into an opportunity for economic growth with clean energy technology innovation, the clean energy technology development strategy set two execution strategies: (1) Prior Investment in Clean Energy Technology Development to Reduce Greenhouse Gas and Support New Industries and (2) Inducement of Private Investment through Establishment of Market-Oriented Policy Foundation, and consisted of the technology development of renewables, efficiency improvement, and demand management in six areas.

– Solar Cell

Solar cells are the main technical field that can determine the performance and price of the photovoltaic system, which is classified into silicon-based and non-silicon-based solar cells according to the light absorption layer material. With respect to the technology, high efficiency and low price are trending, and the market is growing around crystalline silicon solar cells.

〈Table 5-1〉 Solar Cell Industry

Descriptions	Contents
Competitiveness	• Silicone: Securing technology and market competitiveness by developing high output products • Non-silicone: Securing world-class technology in next-generation solar cells such as perovskite
Market conditions	• Progressing in distribution and expanding photovoltaic power generation through policy support such as Renewable Portfolio Standard (RPS) and photovoltaic rental business • The proportion of photovoltaic energy of renewable energy is projected to be 14.1% by 2035.
Photos	 

– Fuel Cell

A fuel cell is a power generation device that directly converts the chemical energy of a fuel into electrical energy by an electrochemical reaction, which is a convergence technology that integrates fuel cell stacks, peripheral devices, fuel converters, and control technologies. With respect to technology

trends, to prepare for the future transition to a hydrogen-economy society, developed countries are developing mid- and long-term plans and implementing technology development, distribution, and standardization projects. The electrolyte membrane fuel cell for the building is a pilot application level, and the molten carbonate fuel cell for power generation is under the demonstration of products introduced for technology and the development of its own model.

〈Table 5-2〉 Fuel Cell Industry

Descriptions	Contents
Competitiveness	• Excellent manufacturing base technology for mass production • Having technologies almost comparable with advanced ones
Market conditions	• ROK's fuel cell market is expected to account for 20% of the global market by 2020. • The fuel cell market for transportation is expected to grow in earnest after 2015, reaching about KRW 800 billion by 2020.
Photos	 

– Biofuel

With respect to biofuel, the United States and Brazil started using bioethanol made of sugar cane and corn as raw materials, which is currently under research related to the industrialization of second-generation bioethanol. In addition, there is active research around the world on fuel and useful substance production from microalgae biomass, and recent research on industrializing high value-added useful materials is under process.

〈Table 5-3〉 Biofuel Industry

Descriptions	Contents
Competitiveness	• Applying the world's best petrochemical technology to biofuel manufacturing is possible. • World's leading group level development and culture technology of microalgae
Market conditions	• The global bioenergy market is expected to expand to 18% of the total energy market by 2030. • As of 2015, the ROK raised its biodiesel blending ratio from 2.0% to 2.5%.
Photos	 National Marine Bioenergy R&D Center, Inha University  Bio-butanol Production Facilities in GS Caltex

– Secondary Battery

Secondary batteries can be converted into electrical energy and stored in the form of chemical energy, and then converted into electrical energy when needed, which means a device is capable of repeatedly performing such conversion. Secondary batteries are changing from small size to medium and large size for use in electric vehicles and power storage devices, and the research and development of various batteries such as a lithium–sulfur battery, redox flow battery, and sodium–ion battery, which are next–generation secondary batteries, are being conducted.

〈Table 5–4〉 Secondary Battery Industry

Descriptions	Contents
Competitiveness	• World's No. 1 market share in lithium–ion secondary batteries based on the predominance of cell manufacturing technology • Rich industrial infrastructure for cell manufacturing
Market conditions	• The trend of expanding from the small size (mobile devices) to the medium and large size (electric vehicles and renewable energy) market • ROK's secondary batteries occupy No. 1 global market share, but the localization rate of parts and materials is less than 40%.
Photos	 Zinc–bromine redox flow battery under demonstration at Daesan Plant, Lotte Chemical

– Power IT

The electric power IT can be divided into an energy management system, renewable hybrid, etc. The Ministry of Land, Infrastructure and Transport and the Ministry of Trade, Industry and Energy are promoting the demonstration of factory energy management system technology that reflects the development and characteristics of each process of building energy management system operation and diagnosis technology to reduce building energy use. In addition, the Ministry of Science and ICT is implementing the development and demonstration of renewable energy convergence technologies and the Ministry of Trade, Industry and Energy is promoting the construction of energy storage devices linked with renewable energy and empirical research in connection with V2G (Vehicle to Grid).

〈Table 5-5〉 Power IT Industry

Descriptions	Contents
Competitiveness	• The EMS has a high potential for success by setting technology development targets related to improved energy savings such as building energy operation management technology and energy integrated management technology reflecting the characteristics of each process.
Market conditions	• The world market size of the EMS is expected to more than double by 2020 compared to 2013 due to strengthened energy demand management and increased investment. • Renewable hybrids are expected to grow rapidly with respect to the renewable energy convergence type energy storage system (ESS), distributed energy resource integration, and V2G technology.
Photos	 V2G demonstration electric vehicle charging station installed in the Gwangju Institute of Science and Technology

– CCS
(Carbon Capture and Storage; carbon dioxide capture and storage technology)

The CCS is a technology that separates carbon dioxides from a large amount of carbon dioxide emission sources, which use fossil fuel as the main energy source, before they are released into the atmosphere and then transports, stores, and isolates them in the ground. With respect to technology trends, the capture process, demonstration and conversion technology, and transportation and storage technology are currently in development, and it is necessary to secure price competitiveness for the CCS market that is not yet formed in the ROK and continue to invest in technology development and demonstration projects.

〈Table 5-6〉 Carbon Capture and Storage Industry

Descriptions	Contents
Competitiveness	• Capture technology: The next-generation capture technology is comparable with that of leading countries, and the commercialization technology has secured a technology related to 10MW pilot-scale demonstration. • Transportation technology: Securing technological competitiveness such as EPC and detailed designs in engineering and heavy industries • Storage technology: Searching for promising storage structure and securing an assessment technology through continuous R&D
Market conditions	• ROK's CCS market is underdeveloped, and it is necessary to secure price competitiveness and expand investment in technology development and demonstration projects.
Photos	 Wet scrubbing capture plant after combustion of 10MW (Boryeong Thermal Power Plant Division)〉  Dry scrubbing capture plant after combustion of 10MW (Hadong Thermal Power Plant Division)〉

– By-product Gas Conversion

By-product gas conversion is a production technology that converts carbon contained in by-product gases or various organic wastes generated by industries such as steel mills and petrochemical plants to produce fuels and chemicals for transportation. With respect to technology trends, to cope with climate change and foster new industries, high value-added research such as by-product hydrogen production and alcohol synthesis are being conducted in various countries. However, for full-scale distribution, it is necessary to overcome the limitations of current technologies.

〈Table 5-7〉 By-product Gas Conversion Industry

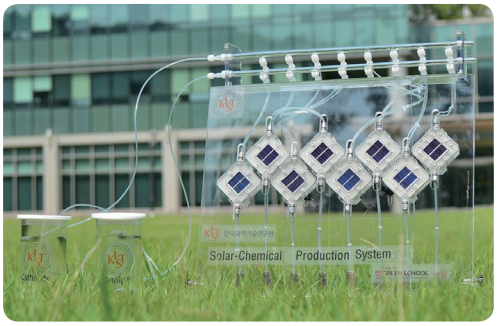
Descriptions	Contents
Competitiveness	• Secured the position of the world leader in petrochemical and steel industries • Recently developing element technologies related to by-product gas resources such as bio, chemical catalyst, and process technology
Market conditions	• 20% of domestic by-product gas generation is utilized and converted into clean fuels and chemicals, KRW 9 trillion worth of added value can be generated annually.
Photos	 Biogas production plant for organic waste to energy, Easy Bio, Inc.

– CO_2 Conversion

CO_2 conversion refers to a technology that directly uses CO_2 to produce chemical materials and fuels. With respect to technology trends, at present, there is no commercial process for converting CO_2 in the ROK, but the attention of the related industries is focused, such as reducing global CO_2 emissions, using it as a renewable energy source and alternative raw material for the chemical industry.

〈Table 5-8〉 CO_2 Conversion Industry

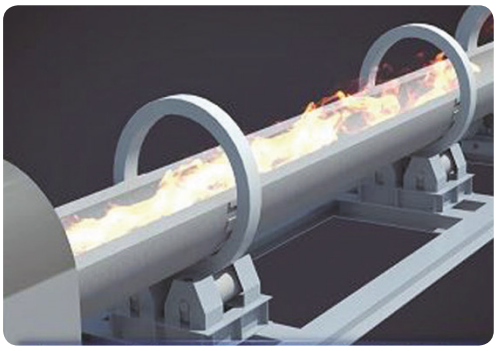
Descriptions	Contents
Competitiveness	• Developing bio-based raw material production source technologies using biotechnology
Market conditions	• Markets related to CO_2 reduction are under development. • 50 million tons CO_2eq., which is more than half of CO_2 world market demand of 80 million tons CO_2eq., are used to promote the recovery of crude oil in North America.

Descriptions	Contents
Photos	 Carbon dioxide polymer developed by Aju University and SK Innovation  Device module for the synthesis of carbon dioxide conversion chemical raw material

– CO_2 Mineralization

CO_2 mineralization is a technique for synthesizing carbonates ($CaCO_3$, etc.) with Direct Carbonation which directly reacts industrial by-products containing Ca, Mg, etc., with CO_2, which is like ash from power plants. With respect to technology trends, technological cooperation projects in response to the Post-2020 New Climate Scheme are being expanded, and investment related to the application of GHG reduction technology for coal-fired power plants is underway.

〈Table 5-9〉 CO_2 Mineralization Industry

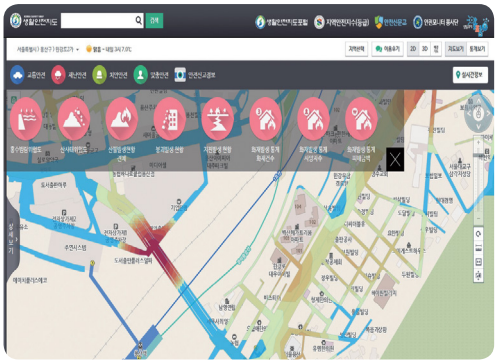
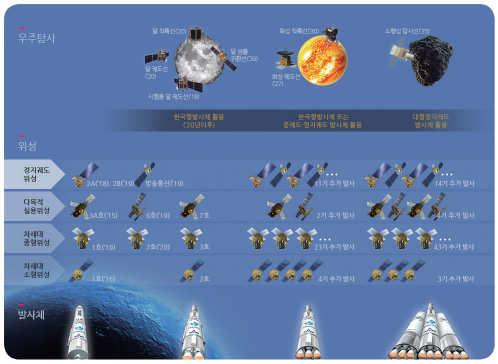
Descriptions	Contents
Competitiveness	• Having world top-class technologies (completed the production demonstration of green cement 2 tons/day and eco-friendly paper 3 tons/day) • Having CO_2 mineralization technologies in lime water and source technologies for producing nanocomposite materials for green cars
Market conditions	• Ash production will be doubled by the capacity expansion (increased by 83%) of coal-fired power plants based on the 6th Master Plan for Electricity Supply and Demand • Power generation by-products are expected to increase from 7.5 million tons in 2010 to 15 million tons in 2020.
Photos	  Low carbon, high-performance green cement demonstration plant built in Danyang plant of Hanil Cement

– Common Platform Technology

Common platform technologies are a wide range of technologies, including climate change monitoring and forecasting, climate risk identification, and climate adaptation technologies. With respect to technology trends, the ROK

established the 2nd National Climate Change Adaptation Measures (2015) and detailed implementation plans to minimize the negative impacts of climate change and to protect the safety and property of its people.

〈Table 5-10〉 Common Platform Industry

Descriptions	Contents
Competitiveness	• Providing data to monitor and forecast climate disasters and establishing bases for expression technologies • Securing source technologies related to observation and IT • Having a precise scale of prediction technology
Market conditions	• Weather information service industry is rising due to abnormal climate caused by climate change. • The economic effect of biodiversity is estimated at KRW 6.72 trillion.
Photos	 Mapping cases for disaster safety information, Ministry of Public Safety and Security  Korea's space development plan, Korea Aerospace Research Institute

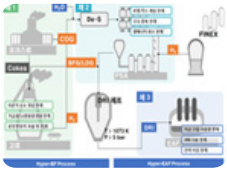
– Efficiency Improvement

The industrial efficiency sector is laying the foundation for the transition to a low energy consumption and low carbon industrial structure by managing the energy distributed and consumed in industries, which are the main consumers of energy resources such as heat and electricity, through integrated industrial energy networking, industrial process high efficiency, ICT-based high-efficiency technology convergence, and developing new high-efficiency processes.

To cope with climate change by developing eco-friendly vehicles which have excellent energy consumption efficiency and meet the pollution-free and low pollution standards, the transportation efficiency sub-sector set the directions of such as improvement of the mileage and cost reduction of electric power-based cars, improvement of fuel efficiency through light weight and efficient energy management, improvement of efficiency and performance and exhaust gas reduction of engine-based cars.

To spread the distribution of zero-energy buildings, the key agenda of the building sector for national GHG reduction, the building efficiency sub-sector is making a global model of the zero-energy community through optimizing energy for urban units by ICT convergence, strengthening competitiveness of core components for zero energy buildings, leading the zero-energy community market through standardization, etc.

〈Table 5-11〉 Efficiency Improvement Goals and Technology Development Strategies by Sub-sector

Item	Industrial Efficiency	Transportation Efficiency	Building Efficiency
Targets	• 82% (2014) → 92% (2025)	• 82.8% (2014) → 94% (2025)	• 80.9% (2014) → 95% (2025)
Strategies	• Converting the existing industries with high GHG emissions to low carbon industrial structures – Integrated management of energy distributed and consumed in the industrial sector – Developing and applying new high-efficiency process to energy consumption industries	• Promoting the next-generation green car and infrastructure market – mproving efficiency and performance of EVs, HYBs, and FCEVs – Responding to global environmental regulations in the transportation sector	• Responding to future society by implementing zero-energy buildings and communities – Expansion of technological achievement distribution such as core parts development and key building optimization – Responding to future convergence technologies such as community network technology
Photos	 High efficiency of energy network industrial complex	 Secondary battery system for EVs	 Zero-energy community
	 CO2 reduced hydrogen steelmaking	 FCEVs and charging infrastructure	

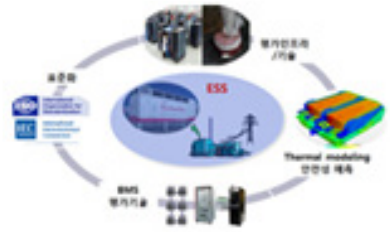
※ Source: Clean Energy Technology Developmental Strategy for Climate Change Response and New Industry Creation (draft), National Science and Technology Council, 2016

– Demand Management

The ESS sub-sector secures global competitiveness through establishing domestic ESS infrastructure and connecting with global markets, such as the expansion of technological competitiveness, discovery of market participation benchmarks, and overseas demonstration for export commercialization, by utilizing the large-scale electric energy storage system (ESS) technology that promotes low cost, high efficiency and stabilization of power through the improvement of power quality of renewable energy and efficient use of fossil fuel-based power resources.

To build a business model-based technology and infrastructure that can sell various forms of energy generated from distributed resources such as renewable energy to the market or individual need or demand, the E-prosumer sector has set the direction of demonstration and infrastructure construction, development of a platform for energy trade activation, discovery of strategies for creation of various industrial ecosystems, etc., for the E-prosumer base.

〈Table 5-12〉 Efficiency Improvement Goals and Technology Development Strategies by Technology

Item	ESS	E-prosumer
Targets	• 82.6% (2014) → 95% (2025)	• 79.0% (2014) → 87% (2025)
Strategies	• Securing global ESS global competitiveness and strengthening export capacity – veloping large-scale energy storage systems with safety and long life – Developing and demonstrating ESS service for securing overseas and new markets	• Establishing E-prosumer initial markets and fostering new industrialization – Activating E-prosumer by increasing participation of ICT companies and startups – Establishing a market trading system and infrastructure of distributed energy sources
Photos	 Performance and safety evaluation-standardization-prediction  Low price high quality large size ESS	 hment of E-prosumer infrastructure

※ Source: Clean Energy Technology Developmental Strategy for Climate Change Response and New Industry Creation (draft), National Science and Technology Council, 2016

1.2 Plan for Research and Technology Development

To cope with the climate change crisis, the ROK is actively pursuing policy efforts to secure GHG reduction and climate change adaptation technologies. As mentioned earlier, the ROK has not only presented the Establishment of a Sound Implementation System for the New Climate Scheme and the Discovery and Support of Eco-Friendly Future Energy as national tasks but also established and is implementing the Climate Technology Roadmap (CTR) as a mid- and long-term plan to support the implementation of the Paris Agreement in terms of national R&D. In addition, in the 3rd Five-Year Plan for Green Growth established in 2019, the ROK presented the Fosterage of Innovative Green Technologies and Industries and a Fair Green Economy as one of the three strategies and plans to promote building a foundation for the dissemination of renewable energy and expand total periodic green R&D investment by 2023. The Ministry of Science and ICT intends to drive innovation growth and preoccupy the new climate market by actively supporting R&D on green and climate technologies, including investing about KRW 100 billion for green and climate technology innovation in 2019.

– Carbon Reduction

To support renewable energy-centered energy conversion, the ROK is developing key source technologies such as solar and wind power and developing key source technologies for eco-friendly carbon-free hydrogen production and high-efficiency hydrogen storage that can contribute to GHG reduction. Particularly, in the field of perovskite solar cells, which are the next-generation solar cells, since the research team led by Sungkyunkwan University Professor Nam-Gyu Park has developed the world's first solid perovskite solar cell, domestic research institutes are leading the world in its technological innovation, and recently the Korea Research Institute of Chemical Technology and MIT collaborated to record the world's highest photoelectric conversion efficiency (25.2%).

– Carbon-to-Resource

The ROK established a roadmap to demonstrate the national carbon-to-resource strategy project in 2016, and the technology to produce chemical materials and fuels by using GHG as a fossil fuel replacement resource is developed by the national carbon-to-resource strategy project group since 2017. The carbon mineral flagship research in relation to the development will demonstrate the technology for producing abandoned mine filler using low concentration CO_2 and ash from power plants in connection with real fields. The ROK also is supporting KRW 141.4 billion for development of C1 gas refinery technology over a nine-year period starting in 2015 and through such project, has made excellent achievements such as succeeding in developing the world's first formic acid production technology using carbon monoxide.

– Climate Change Adaptation

The ROK has presented a scientific climate change risk management system as a policy task through the 2nd National Climate Change Adaptation Measures and continues to develop technologies to adapt to climate change in the areas of agriculture, livestock, fisheries, forestry, infectious diseases, and water management. The government plans to invest a total of KRW 200.9 billion in R&D to respond to climate change in agriculture from 2020 to 2027 to proactively respond to the impact of climate change on agriculture and is developing satellites that can monitor the status of water resources and disasters throughout the Korean Peninsula in response to abnormal climate and water management due to climate change.

2. Systematic Observation

Climate service refers to the provision of climate information that reflects the needs of users that can be used in their decision-making process. The ROK has established and implemented the Climate Work Development Master Plan with a five-year planning period. The 3rd Climate Work Development Master Plan (2017-2021), established in 2017, sets the Expansion of Climate Change Observation and Monitoring System as one of the four key action strategies. To achieve the target, the establishment of the global climate monitoring system, development, and operation of weather satellites, and development of satellite-based climate change monitoring technology were set as its detailed targets.

The World Meteorological Organization (WMO[31]) has been working to efficiently provide climate information and services through the Global Framework for Climate Services (GFCS[32]) since 2009. GFCS consists of five main elements including observation/ monitoring, research/ modeling/forecasting, a climate service information system, and user interface platforms and the development of capabilities that can be applied comprehensively to these four elements.

The observation and monitoring field collects grid-based observation data, including through satellites and radar, in addition to the branch centers' observation data. For Automatic Weather Station (AWS) data, the data managed by the Rural Development Administration and the National Institute of Forest Science are collected. The modeling and forecasting data is broken down into very short-term forecasts (within 6 hours), short-term forecasts (within 3 days), mid-term forecasts (within 10 days), and long-term forecasts (with 11 days or more), and forecast information on various time scales is being produced mainly by the Korea Meteorological Administration in accordance with the forecast period set by the Weather Act.

For climate change scenario data, HadGEM2-AO, the UK's model for predicting climate change, has been introduced for all global regions. Finally, for the East Asia region, 50km resolution data in conjunction with CORDEX[33] international project are provided, and for the area of Korean Peninsula, 135km spatial resolution data are provided by producing 12.5km resolution data using HadGEM3-RA, the UK's regional climate model, without removing systematic errors in climate models.

For the climate service information system, weather-related information, such as observations and short-term forecasts, is provided through the

31 WMO: World Meteorological Organization
32 GFCS: Global Framework for Climate Services
33 CORDEX (COordinated Regional climate Downscaling EXperiment): International joint research for regional climate forecast

Weather Information website[34], and climate-related information, such as long-term forecasts and climate change scenario data, is provided through the Climate Information site[35]. The weather observation information of the Rural Development Administration and the National Institute of Forest Science mentioned above are provided separately through the Agricultural Weather Information website[36] and the Mountains Weather System[37].

2.1 Atmosphere Observation System

The global atmosphere watch observation network for the Korean Peninsula observes 36 elements in all atmospheric deposition areas including GHG, reactive gases, aerosols, atmospheric radiation, stratospheric ozone, and ultraviolet rays, recommended by the Global Atmosphere Watch Program. In addition, the ROK provides high-quality observation data representing Northeast Asia and is actively involved in international networks and related programs through its research activities.

It was designated as a WCC[38] for sulfur hexafluoride by WMO in 2011 in recognition of the measurement technology of sulfur hexafluoride (SF_6), which is one of the representative GHGs and is present in the atmosphere in extremely small amounts. In 2016, to produce reliable data and provide a variety of information, it improved the quality control techniques of GHGs, added the results of NOAA's[39] GHG flask observation and analysis conducted as part of the US-Korea Meteorological Cooperation, and newly presented an analysis by altitude of vertical ozone data. In 2017, it has obtained good results from the WCC's conformity assessment with regard to the observation environment, equipment operation, and data sharing of GHG and reaction gases, which has become an opportunity to increase reliability in the production and quality control of data. The results can be found on the WMO and GAW websites[40].

The ROK's global atmosphere watch operates as of 2019 four basic observatories to monitor climate change in Anmyeondo, Gosan, Ulleungdo including an unmanned climate change monitoring station in Dokdo; one secondary station in Pohang; and seven entrusted observatories at universities and related institutions.

34 Weather Information website: https://data.kma.go.kr/cmmn/main.do
35 Climate Information website: http://www.climate.go.kr/home/
36 Agricultural Weather Information website: http://weather.rda.go.kr/index.jsp
37 Mountains Weather System: http://mw.nifos.go.kr/Main/
38 WCC: World Calibration Center
39 NOAA: National Oceanic and Atmospheric Administration
40 www.wmo.int/pages/prog/arep/gaw/other_pub.html

〈Table 5-13〉 Korean Peninsula Climate Change Monitoring Network Information

Classification	Institution Name (Observation point name)	Observation Area	Remarks
Basin and Secondary Observatories	Anmyeondo Climate Change Monitoring Station	Greenhouse Gas, Reaction Gas, Aerosol, Total Atmospheric Deposition, Stratospheric Ozone, Ultraviolet Rays, Atmospheric Radiation	Basic observatory WMO GAW Regional observatory (1999, AMY)
	Gosan Climate Change Monitoring Station	Greenhouse Gas, Aerosol, Total Atmospheric Deposition, Stratospheric Ozone, Ultraviolet Rays, Atmospheric Radiation	Basic observatory WMO GAW Regional observatory (2013, JGS)
	Ulleungdo-Dokdo Climate Change Monitoring Station	GHG, Reaction Gas, Aerosol, Total Atmospheric Deposition, Ultraviolet Rays	Basic observatory
	Dokdo Unmanned Climate Change Monitoring Station	GHGs	Basic observatory
	Pohang Observatory	Stratospheric Ozone, Ultraviolet Rays	Secondary observatory WMO GAW Regional observatory (1994, POH)
Entrusted observatory	Yonsei University	Stratospheric Ozone, Ultraviolet Rays	
	Gangwon Regional Meteorological Administration	Aerosol, Vertical Distribution	
	Seoul National University	Forestry, Carbon Dioxide	
	King Sejong Station of the Korea Polar Research Institute	Carbon Dioxide	
	Jang Bogo Station of the Korea Polar Research Institute	Carbon Dioxide, Stratospheric Ozone	
	Jeju National University (in Jeju)	Radon	
	Sookmyung Women's University (in Seoul)	Middle Atmospheric Water Vapor, Stratospheric Ozone	

2.2 Marine Observation System

The ROK established the 2015-2020 Marine Survey Master Plan as the highest comprehensive master plan in the field of marine surveys and appointed the Korea Hydrographic and Oceanographic Agency (KHOA), which is responsible for the National Maritime Observation Network, and related agencies such as the National Fisheries Research and Development Institute, the Korea Meteorological Administration, and the Korea Marine Environment Management Corporation as implementing institutions for marine surveys, data production, and information provision in response to the 21st century new ocean order.

As of 2018, the KHOA established a network of 132 national maritime observatories consisting of tide stations, ocean stations, marine observation buoys, seawater flow stations, and comprehensive marine science bases. Through these, various observational data such as tides, water temperature, waves, ocean currents, and sea weather are collected, analyzed and disclosed.

The KHOA operates the Korea Ocean Observing and Forecasting System (KOOFS) to provide comprehensive marine observation data. KOOFS, as a system that analyzes and provides forecast information and real-time observations on tides, tidal currents, and ocean currents based on marine GIS information and satellite water temperature information, not only provides

the East Sea current chart and ocean information service but also allows users to browse the metadata of domestic and international observation and forecast data.

〈Table 5-14〉 Classification and Types of National Ocean Observation Network

Observation Network	Observation Items
Tide station	Tides, Water Temperature, Salinity, Temperature, Atmospheric Pressure, Wind Direction, Wind Speed
Ocean station	Tides, Waves, Temperature, Atmospheric Pressure, Wind Direction, Wind Speed
Marine science base	Tides, Water Temperature, Salinity, Weather, Environment
Seawater flow station (HF-Radar)	Surface seawater flow
Marine observation buoy	Ocean (flow rate, flow direction, water temperature) and weather (wind direction/ speed, atmospheric pressure, temperature)
Other marine observation buoys	Ocean (flow rate, flow direction, water temperature) and weather (wind direction/ speed, atmospheric pressure, temperature)

※ Source: National Maritime Observation Network Annual White Paper, Ministry of Oceans and Fisheries, 2017

2.3 Land Observation System

– Agricultural Observation System

The agricultural meteorological observations are of meteorological phenomena closely related to agriculture, which are carried out in ten secondary agricultural meteorological observation offices located throughout the nation including the Suwon Weather Station (the Seoul Metropolitan Office of Meteorology since 2015), the basic agricultural meteorological observatory in accordance with the WMO technical regulations.

Since the late 1990s, regional rural development institutions such as Si/Gun agricultural technology centers installed automatic weather systems and began to use meteorological data to spread agricultural technologies such as pest monitoring, fertilization amount determination, and crop prediction. The number of meteorological observation points linked to the Rural Development Administration's agricultural weather network is 212 as of December 2018, which provide detailed information on agricultural weather in the main areas where crops are produced. There are nine agricultural weather observation elements: temperature, precipitation, solar radiation, soil temperature, and soil moisture, which are closely related to crop growth. They are measured at one-minute intervals, collected at 10-minute intervals, and provided to consumers, such as farmers, policymakers, and researchers.

The agricultural meteorological information system has been expanded and constructed for four purposes depending on its consumer. The first purpose is for farmers[41], which provides information on past and present agricultural weather observations and agricultural meteorological analyses, etc. The second one is for personnel[42] in charge of agricultural meteorology in

41 Agricultural Meteorological Information System (for farmers): http//weather.rda.go.kr

42 Agricultural Meteorological Information System (for personnel in charge of agricultural meteorology): http://weather.rda.go.kr/awsadm

Si/Gun agricultural technology centers, which provides detailed agricultural weather information, weather signboard management, etc. The third one is for agricultural weather control[43], which provides remote management of observation data and AWS branch management. The final one is for researchers[44], which provides meteorological characteristics and abnormal weather analysis information by agricultural climate zone.

– Forest Observation System

The National Institute of Forest Science has built a meteorological observation network in mountainous areas since 2012 and plans to increase the scope of the project to the Korea Forest Service's (KFS's) policy project from 2017 to build 420 additional stations over the next five years to use the network in scientific forest management as well as forest disaster prevention. As of 2017, 200 mountain observatory network observes seven factors every minute, including temperature, wind, and precipitation, and the observed data is collected by the National Institute of Forest Science of KFS and then jointly used for national weather and climate observations in conjunction with the Korea Meteorological Administration.

In 2018, to share real-time mountain weather information observed in major mountains of the nation, the National Institute of Forest Science established a weather data transmission system and developed a mountain weather information system to complete the data linkage system between ministries. Such shared weather information is used to produce high-quality forest disaster forecast information and improve the safety of the people through data fusion among ministries such as Korea Meteorological Agency, Ministry of the Interior and Safety, Ministry of National Defense, and local governments.

The Korea Meteorological Administration has been cooperating with other ministries since 2012 to ensure the quality control of observation data and reliability of the data. Forest fire and landslide risk information analyzed by KFS is used as basic data for the life safety guidance service of the Ministry of the Interior and Safety, and this important information is published to enhance public safety. Also, the Weather Group of the ROK Air Force of the Ministry of National Defense actively utilizes the information on mountainous weather and forest disaster risk provided by KFS, which established a mutual cooperation plan with industries, such as maintenance and management of observation equipment, to strengthen the role and function of the national mountain weather observation network.

43 Agricultural Meteorological Information System (for agricultural weather control): http://weather.rda.go.kr/wmsadm

44 Agricultural Meteorological Information System (for researchers): http//weather.rda.go.kr/zone

〈Table 5-15〉 Types and Contents of National Mountain Meteorological Observation System

System	Descriptions	Contents
Mountain weather observation system	Observation elements	Wind Direction, Wind Speed, Humidity, Precipitation, Atmospheric pressure, Ground Temperature, etc.
	System description	Screens that display real-time weather conditions of the current mountain weather observation network, which is automatically updated with new data every minute.
Mountain weather observation System	Observation elements	Wind Direction, Wind Speed, Humidity, Precipitation, Atmospheric pressure, Ground Temperature, etc.
	System description	Providing the real-time weather of mountains (forest weather observation network data of the National Institute of Forest Science), flatlands (Digital Forecast of the Korea Meteorological Administration), satellites, 100 famous mountains, and natural recreation forest and weather special reports through public service

※ Source: National Institute of Forest Science, 2018

2.4 Satellite Observation System

The ROK successfully launched the Chollian (satellite) in June 2010, making it the seventh country that has a meteorological satellite in the world following the United States, Europe, Japan, Russia, China, and India. In addition, as the end of the operational life of the Chollian (7 years) has arrived, the ROK launched the Chollian 2A as its replacement satellite on December 5, 2018.

The Chollian 2A is expected to improve the performance of temporal resolution (global observation cycle is improved to 10-minute intervals (18 times) from three-hour intervals, and Korean Peninsula observation cycle is improved to two-minute intervals (7.5 times) from 15-minute intervals, spatial resolution (visible channel is improved to 0.5-1km interval from 1 km, and infrared channel is improved to 2 km interval (about 4 times) from 4 km, observation channels (improved from 5 to 16 channels), types of outputs, etc. compared to the existing Chollian. By these improvements, the outputs of the Chollian 2A will be widely used in various areas such as the short-term forecast (convective clouds, precipitation, clouds, fog, etc.), typhoon and marine (location and intensity of typhoons, ocean and sea surface wind, etc.), convergence (drought, floods, soil moisture, forest fires, etc.), and climate change and environment (core climate variables, fine dust, yellow dust, etc.).

In addition, the satellite contains a space weather payload capable of observing three space weather observation elements (particle flow monitor, earth magnetic field meter, satellite charging monitor). Therefore, the performance including the spatial resolution, three times in the number of observation channels, and five times faster coverage of disaster phenomena, which local observation on space weather such as proton and electron flux, magnetic field strength, and satellite electrification while positioned in geostationary orbit, has been improved. In addition, real-time monitoring of lightning activity and space weather has become possible.

The Chollian 2A will produce and provide 52 kinds of outputs through the Advanced Meteorological Imager (AMI) sensor: 14 kinds of outputs such as cloud cover, cloud form, the height of cloud ceiling, rainfall intensity,

rainfall probability regarding clouds and precipitation, 14 kinds of outputs such as aerosol detection, optical depth, particle size distribution, visibility, volcanic ash detection regarding to radiation and aerosol, and 11 kinds of outputs such as icing, atmospheric motion vector, stability index, and perceptible water regarding to atmosphere and aviation as well as 13 kinds of outputs such as clouds, forest fires, and fog detection regarding scenes and indicators. Three kinds of space weather observation information for high energy particle flux, magnetic field strength, and satellite's electrification state will also be produced through the space weather payload.

Next-generation meteorological satellites are expected to greatly diversify the utilization of satellite information as the space-time resolution, number of observation channels, and types of outputs are improved over conventional satellites. Ten typical applications of next-generation meteorological satellites are typhoons, dangerous weather, marine, fine dust, forest fires, fog, icing, volcanic eruptions, space weather, etc.

The Ministry of Oceans and Fisheries successfully launched the world's first geostationary oceanic surveillance satellite, the Chollian on June 27, 2010, and has made regular observations since April 1, 2011. The Chollian can collect basic images of the marine environment such as sea waters around the Korean Peninsula, Asia and the rest of the world. The Chollian designed for oceanography and meteorological observation is still carrying out maritime observation missions.

The Chollian is used in various fields such as the physical characteristics detection of the ocean including red tide, high water temperature, and cold pool, marine debris monitoring, and marine environment change observation after its launching, and its utilization is expected to expand.

In addition, with the spread of the perception that understanding of the ocean is essential to cope with climate change such as global warming, countries around the world are actively conducting technology development and research on marine observation, including satellites. Since the demand for satellite information continuously increases in accordance with ocean research trends, the ROK started to develop GEO-KOMPSAT-2B (Cheonlian 2B) in October 2012, a next generation satellite, to succeed the mission of the Chollian.

GEO-KOMPSAT-2B, as a next generation satellite of the Chollian rather than simply succeeding the Chollian's duties, will provide higher-quality satellite information by significantly improving performance such as spatial resolution, number of observations, and expansion of observation items. Currently, the assembly of GEO-KOMPSAT-2B has been completed and is under performance tests to perform its mission in space, and it is expected to be launched in March 2020.

[Rain Gauge] Instrument used to measure rainfall in the Joseon Dynasty period

CHAPTER 6

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International Support and Awareness of Climate Change

1. Financial Support
2. Technology Development and Transfer
3. Capacity Building
4. Public Awareness and Public–Private Cooperation

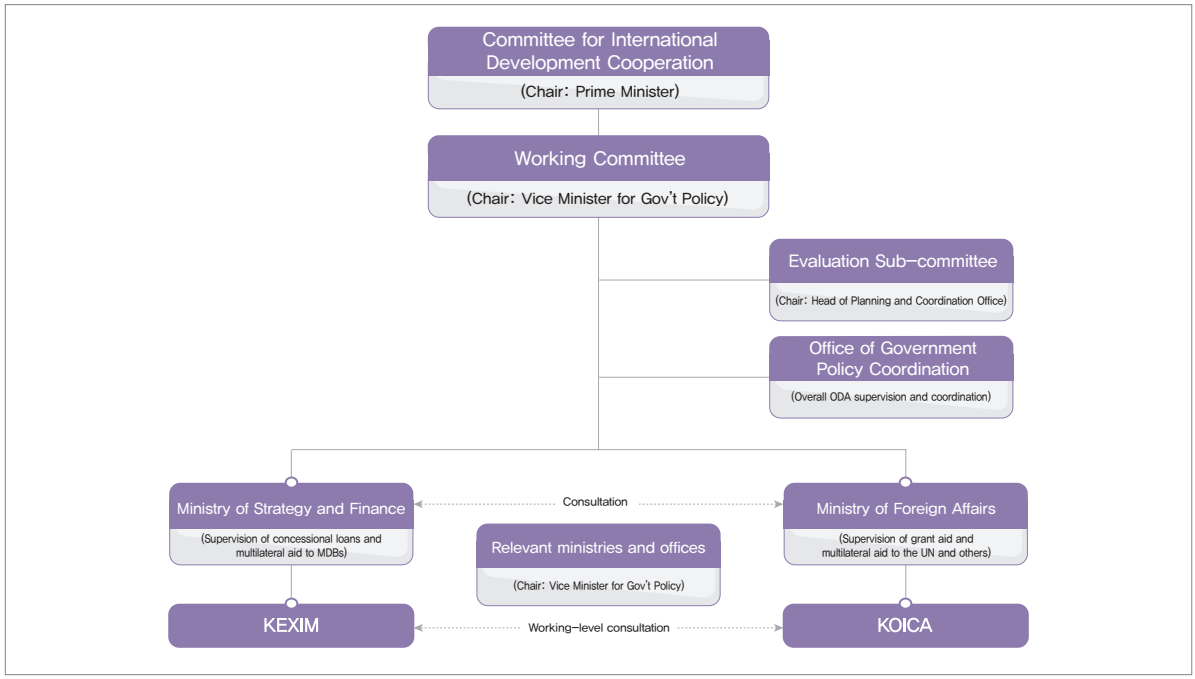
1. Financial Support

The ROK acknowledges the importance of cooperation among nations for climate change response and has been amplifying its assistance to developing countries to cope with climate change. The ROK will share the related information by this report and continues to participate in the cooperative efforts of the international community.

The ROK is providing concessional loans and grant aid, through the ODA (Official Development Assistance) and other means for developing countries and voluntarily carries out assistance projects such as technology development and transfer and capacity building. At the same time, the ROK is gaining expertise from the European Union via the EU-Korea Emissions Trading Scheme Project (2016-2018) and continues to enhance its capacity related to climate change mitigation.

The ODA of the ROK is supervised and coordinated by the Committee for International Development Cooperation chaired by the Prime Minister in accordance with the Framework Act on International Development Cooperation, and the head of OPC (Director-General for Development and Cooperation Policy) serves as the secretary of the committee. While concessional loans are supervised by the Ministry of Strategy and Finance and implemented by the Export-Import Bank of Korea (KEXIM), grant aids are supervised by the Ministry of Foreign Affairs, and implemented by the Korea International Cooperation Agency (KOICA). Other individual ministries and local governments are also engaged in grant aid projects based on their expertise.

[Figure 6-1] ROK's ODA Implementing Arrangements



While overcoming struggles of the global financial crisis and rising financial deficit, the ROK is making efforts to contribute as a member of the international community. Under the 1st International Development and Cooperation Master Plan (2011–2015), the amount of ODA grew by an annual average of around 12% from USD 1.17 billion to USD 1.85 billion, which is quite high compared to other donor countries. In addition, the 2nd International Development and Cooperation Master Plan (2016–2020) was established in 2015 and is currently being executed.

Meanwhile, an implementation plan incorporating both concessional loans and grant aid is established every year, based on which the ROK is assisting developing countries. The general direction for international development cooperation reflected in the ROK's 2018 Implementation Plan for International Development Cooperation established in June 2017 is as follows:

The ROK plans to distribute ODA resources and implement projects focused on strengthening assistance for recipient countries achieving the Sustainable Development Goals. In particular, with respect to climate change mitigation response, the ROK plans to assist in 45 projects in 2018. For climate change adaptation, the ROK plans to enhance the capabilities of developing countries by carrying out projects for improving water resource safety and sanitation, such as water and sewage treatment and drinking water facilities, comprehensive development and transfer of farming techniques for self-reliant rural communities, etc.

At the UN Climate Summit in September 2014, the ROK announced the contribution of USD 100 million to the Green Climate Fund (GCF) and is taking the initiative in mobilizing the initial funds for GCF after concluding the contribution agreement of USD 100 million equivalent in June 2015. Also, the ROK established the Global Green Growth Institute in 2012 and contributes USD 10 million annually as a contribution to international organization to support developing countries' transition to green growth and response to climate change. The financial support provided via multilateral institutions continued to increase from KRW 38,657 million in 2014 to KRW 103,675 million in 2017, which accounted for the average annual growth rate of 38.9%, and the financial support through bilateral, regional, and other channels continued to increase from KRW 72,978 million in 2014 to KRW 171,547 million in 2017, which accounted for the average annual growth rate of 32.9%.

For concessional loans, KEXIM develops climate change-related projects as a top priority financing solar power stations, small hydroelectric power stations, environment-friendly transportation, waste treatment, etc., and pays special attention to related projects by offering preferential treatment.

〈Table 6-1〉 Status of Financial Assistance and Support (2014-2017)

Descriptions	Year	Financed Total Amount	
		million KRW	thousand USD
nancial support provided via multilateral institutions	2014	38,657	36,709
	2015	68,909	60,912
	2016	101,438	87,657
	2017	103,675	91,696
Financial support provided through bilateral, regional, and other channels	2014	72,978	69,301
	2015	339,564	300,153
	2016	68,533	59,050
	2017	171,547	151,730

※ Source: Export-Import Bank of Korea
※ Exchange Rates of Korean Won (KRW) per 1 USD (2014-2017):
KRW 1,053.064/USD (2014), KRW 1,131.309/USD (2015), KRW 1,160.589/USD (2016), KRW 1,130.635/USD (2017)

2. Technology Development and Transfer

Ahead of the adoption of the Paris Agreement, the ROK designated and registered the Ministry of Science and ICT as a National Designated Entity (NDE) for technology development and transfer at the end of 2015. After this, the Ministry of Science and ICT established relevant policies and strategies and supported their implementation to promote international cooperation in climate technology in accordance with the UNFCCC.

The ROK has established a global climate technology cooperation model in terms of policy and strategy and supports the development and diffusion of domestic climate technologies. The ROK established the Global Technology Cooperation Promotion Strategy for Climate Change in September 2015 and decided to actively participate in the technical mechanisms[45] established and operated on the basis of the UNFCCC. Also, it established the Climate Technology Roadmap (CTR)[46] in 2016 and revised it in 2018. After this, the Ministry of Science and ICT established the Mid- to Long-term Plan for Climate Technology Cooperation (2018-2020) in 2018. The five key tasks pursued by the plan include ① support R&D based on innovation technology, ② systematization of global climate technology cooperation projects, ③ foundation for climate technology cooperation, ④ activation of the participation in technology mechanisms, and ⑤ governmental departments' cooperation.

Multilateral support has been provided to implement technical cooperation. First, the ROK launched a 2.5 billion won climate technology localization

45 A system that supports smoother development and transfer of climate technology between parties under the UNFCCC

46 CTR stands for Climate Technology Roadmap, which is a strategy for managing the R&D of the government's climate technologies to achieve Korea's Nationally Determined Contributions (NDC). It is composed of three technology groups (carbon reduction technology, carbon utilization technology, climate change adaptation technology), top ten climate technologies, and 50 detailed technology groups.

project to support developing countries' response to climate change based on excellent climate technology in 2017. The project carried out 13 support projects, such as identifying technology demand, feasibility study for promising technology cooperation projects, and technology demonstration in developing countries. In addition, the ROK has been organizing the Korea Climate Technology every year since 2017 to gather many stakeholders related to climate technology to promote R&D for climate change and Korea's climate industry. This supported networking where public officials in developing countries and relevant national organizations can communicate directly and lead to efforts to identify regional demand and to link with new technical support cooperation projects.

Second, the ROK supported various climate technology cooperation activities through the Climate Technology Center and Network (CTCN), an organization for implementing technological mechanisms. The CTCM made efforts to spread and raise awareness of international cooperation in climate technology. As a result, the number of CTCN members in the ROK has grown from 9 in 2015 to 51 as of October 2018, which is the largest number of CTCN member institutions in the world. Also, the CTCN operated the Korean CTCN member council for these member institutions since 2016, having seven meetings and disseminating information on international climate technology cooperation.

In July 2018, the ROK hosted the 2018 CTCN Asia-Pacific NDE Regional Forum in Seoul jointly with CTCN. The representatives of NDE, UN Climate Change Conventions, CTCN, and GCF from 19 countries in Asia-Pacific and more than 80 domestic and international experts in climate technology participated in the Forum to discuss ways and technical solutions to cope with climate change. Also, the UNFCCC TEM (Technical Experts Meeting) was held in conjunction with the regional forum on the theme of water, energy, and food.

[Figure 6-2] CTCN Asia Pacific Regional Forum: Group Photo (Left) and Group Discussions (Right)

In addition, as a result of actively supporting Korean CTCN member organizations to perform CTCN technical assistance (TA)[47] projects, the ROK received four TA projects. Moreover, the Ministry of Science and ICT decided to implement the CTCN Pro bono TA[48] project in 2018. Along with this, in consultation with CTCN and the NDEs in developing countries (Ethiopia, Sri Lanka, Serbia), the ROK supports the TA requested by these three developing countries through domestic climate technology institutes.

〈Table 6-2〉 ROK's CTCN TA Business Order Obtainment Progress

① **Guinea)** supporting the training of climate change experts and fiscal linkage planning (Nov. 2016 – Apr. 2017)
② **(Kenya, two orders)** Technology planning for sustainable water resource service and GCF linkage (Dec. 2016 – Jun. 2017, and Oct. 2017 – Mar. 2018)
④ **(Bangladesh)** Planning of household seawater desalination and low-cost housing technology business (Dec 2017 – Jul. 2018)

〈Table 6-3〉 ROK's Pro Bono CTCN TA Progress

① **(Ethiopia)** Technical support for the light rail-based public transportation system for Addis Ababa (Dec. 2018 – Nov. 2019)
② **(Sri Lanka)** Technical support for building the climate-smart city (application area) (Dec. 2018 – Nov. 2019)
④ **(Serbia)** Technical support for building a district heating system based on renewable energy (Dec. 2018 – Nov. 2019)

Third, the ROK has made efforts to build and share information. The ROK built the Climate Technology Information System (CTis), a consumer-specific data platform that provides specialized information specific to international climate technology cooperation. Also, to provide supply and demand information on climate technology cooperation, the ROK has published the Green Climate Technology White Paper since 2016 to establish a new climate technology classification system and gradually expand the range of technology.

The ROK created the foundation for climate technology cooperation to implement the new climate scheme and at the same time, promoted technological cooperation by utilizing technological mechanisms in accordance with the UNFCCC. In particular, it promised to contribute KRW 1 billion to CTCN and contributed KRW 200 million in 2017 and KRW 400 million in 2019. It will contribute the remaining KRW 400 million in 2020. The ROK will endeavor to continue international climate technology cooperation activities and share its experiences.

47 Technical Assistance (TA): It is implemented in a way that CTCN makes an open tender to CTCN member organizations for a TA requested by developing countries, and the winning institution provides funds and professionalism.

48 It is a way for a contributing country or specialized institution to provide "its own" resources or expertise for TA requested by developing countries.

3. Capacity Building

To strengthen the capacity of developing countries to respond to the climate environment, KOICA has opened 15 training courses during 2014–2018, including the reinforcement of national development policy capacity in response to climate change, forest complex management to respond to climate change in Latin America, renewable energy and waste-to-energy to respond to climate change, sustainable water management in response to climate change, and special courses for the Pacific Islands. A total of 123 trainees participated in the courses.

The Greenhouse Gas Inventory & Research Center of Korea (GIR) has held a 3 to 4 weeks professional training programs every year to build the capacity for GHG management in developing countries. GIR invites government officials and researchers from non-Annex I countries to participate in intensive lectures and hands-on exercises on GHG inventory preparation and mitigation modeling analysis by sector.

29 trainees from 28 countries graduated from the 4th training program in 2014, followed by 34 trainees from 26 countries in 2015, 30 trainees from 23 countries in 2016, and 28 trainees from 28 countries in 2017. The number of countries seeking to participate in the training program is steadily increasing, and the ROK is internationally recognized for its excellence in the training programs and signed a memorandum of understanding with the UNFCCC secretariat in March 2017 to jointly run the training program.

[Figure 6-3] UNFCCC-GIR-CASTT Programme on GHGs: Opening Ceremony (Left), Practice (Right)

GIR has also convened the Cooperative Green Growth Modeling Forum (C2GMF) on an annual or semi-annual basis since 2011 to assist developing countries in establishing GHG reduction targets and building capacity to evaluate the progress of mitigation actions through modeling analysis. By 2017, 12 forums had been held and 4 joint research projects (power, waste, buildings, residential, transportation, and forest sub-sectors) have been carried out.

In addition, during the 2016 forum in which nine Asian countries participated, GIR commenced the new Capacity Building Initiative for Nationally Determined Contributions (CBINDC). Since then, C2GMF shared national GHG reduction targets, domestic progress on mitigation actions, National Communication preparation state, and areas that require Mitigation potential analysis among participating countries.

Meanwhile, the KFS carries out climate change-related projects to prevent the land-use change of forest areas jointly with developing countries including Indonesia, Myanmar, and Cambodia. KFS assists the Reducing Emissions from Deforestation and Forest Degradation (REDD+) in developing countries by establishing and implementing measures for preventing forest destruction and on-site projects as they help developing countries identify the reason for land-use change and deforestation. KFS also provides capacity building programs to government officials and relevant persons from developing countries for national forest monitoring systems and GHG reduction strategies. From 2012 to 2016, 129 people from 11 countries were invited and received capacity building training.

4. Public Awareness and Public-Private Cooperation

4.1 Climate Change Education and Promotion

- Courses by Trainee

The ROK strengthens education and public relations on climate change conventions and global warming, through which it draws national consensus on the burden of obligation and creates conditions for individual consumers to make voluntary efforts. For this purpose, it systematically and concretely approaches each subject, means, and stage to provide differentiated education and promotion for each class.

The regular curricula of elementary, middle, and high schools reflect relevant contents such as the Climate Change Convention and energy saving to implement systematic environment and energy education, and related education is also provided through the school's discretionary activities. Also, energy-saving pilot schools and environmental conservation pilot schools are designated and operated, respectively. In addition, the ROK focuses on fostering international experts related to policy response and negotiations, training dedicated personnel on climate change covenants in companies, and the research related to statistical analysis, etc.

The government builds climate policy partnerships with industries and private organizations to raise awareness of the seriousness of global warming and to form a consensus across the nation to increase the effectiveness of climate change measures. Also, the government promotes the dangers of global

warming to the whole nation and strengthens public relations so that people can participate in the reduction of GHG. To promote the public relations (PR) specialized for each target segment of the population, the government has divided the PR target people into public opinion leaders, industry workers, and the general public to increase the efficiency of the PR by differentiating the focus of PR.

1) General Policy on Education, Training and Public Awareness

Korean people are becoming increasingly aware of the seriousness of climate change. Therefore, the government has established education, training, and public awareness policies in the 1st Climate Change Response Master Plan to expand the practice of low carbon living and promote the participation of non-governmental stakeholders in responding to climate change. The government has set a goal of "reducing greenhouse gases in everyday life" and prepared a plan for the public participation campaign using various media. Promotional contents are developed to raise awareness of climate change and spread low-carbon life by developing promotional contents, and campaigns to raise public awareness through the use of media and social media are planned. In the agriculture sector, the consumer awareness of certified low-carbon agricultural products with relevant carbon emissions information will be raised, and the agricultural products will be actively promoted through civic groups to stimulate their consumption.

To prepare a policy on public awareness, the government also aimed to provide closely related education and information, and it plans to provide people with information which is closely related to everyday life. In the field of climate change adaptation, a customized climate change adaptation education program will be developed and operated, which will be set up to prepare National Action Tips, etc., to prevent damage caused by abnormal temperatures such as heat and cold waves.

2) Elementary, Middle and High Schools Curriculum

Rather than performing research and operating education programs related to climate change education around older generations, it is necessary to focus on future generations. In particular, activity-based learning methods, rather than passive lecture-oriented education, are applied to children who may be considered to be parties to climate change so that they can directly experience things to raise the effectiveness of education.

The ROK revised its curricula and increased the weight of contents related to climate change in 2007 and revised the curricula in 2009 to address the issues related to climate change, which has been addressed as one of the global environmental issues in the existing environmental problem area, at the large-scale level of understanding and responding to climate change. It also partially reflected the causes, phenomena, and responses to climate change

in accordance with the relevant curriculum. In addition, elementary school supplementary materials and teacher manuals for climate change education were developed and distributed. As a result, the elementary school curricula deal with climate change in the courses of society and science and the high school science course includes sections on energy and climate change.

3) Education Training for Experts

(Education Training for Energy and Climate Change Experts) The Korea Energy Agency is trying to rationalize the use of energy by making efforts towards nationally saving energy, improving device efficiency, responding to climate change, and expanding the distribution of new and renewable energy through training experts in the field of energy and climate change. The education is operated as a specialized curriculum tailored to the trainees of energy and climate change, including the latest national energy policy, saving technology, operation know-how, etc., by sector such as industry, buildings, and public service. The education target people include local government officials, energy personnel in public institutions, and energy personnel in buildings and industries.

〈Table 6-4〉 Yearly Training Results on Energy and Climate Change Experts

(Unit: person)

Description	Total	2013	2014	2015	2016	2017
Compulsory Education	5,006	833	1,052	903	1,257	961
Fostering Education	7,025	1,254	1,383	1,469	1,512	1,407
Training Education	5,396	1,125	1,116	1,096	1,133	926
Total	17,427	3,212	3,551	3,468	3,902	3,294

※ Source: 2018 KEA Energy Handbook, Korea Energy Agency, 2018

The training program has strengthened the expertise of energy workers related to energy and climate change in a variety of sectors, including industries, buildings, government officials and public institutions. In the future, specialized energy-related curricula in 10 fields in three areas of compulsory/fostering, public officials/public service, and duties/qualification will be operated.

(Education Training for Greenhouse Gas Experts) Training courses for GHG experts operated by the Korea Environment Corporation under the Ministry of Environment are contributing to revitalizing related industries and creating new jobs by training tailored human resources to meet the workforce needs of the climate-friendly industry and providing specialists on climate change as needed by companies and local governments. The training target people of this education are prospective graduates and graduates of four-year colleges in the fields of environment, chemical engineering, energy, and similar fields to industry and economics. The education is a project that links

the employment of the trainees who complete the education to environment-friendly and greenhouse gas management-related companies.

(Education Training for Waste-to-Resource Experts) The Ministry of Environment promoted the Eco-Star project as part of the next generation core environmental technology development project. The Ministry of Environment has carried out the Waste Resource-to-Energy Technology Development Project since 2013 to raise the domestic technology level to 90-95% compared to developed countries by 2020, which is a state-of-the-art global technology capable of leading the global market by 2030. It plans to; in the first phase, pursue empirical research on the technology already secured in connection with the Eco-Star project, in the second phase, develop commercialization technology to secure growth engines in the field of waste resource-to-energy, and in the third phase, discover and develop technologies and additional tasks for cutting-edge globalization.

In the ROK, about 7,000 students who have studied environmental subjects are graduated annually. However, the high-ranking human resources of master's or doctoral level are 14.3% of university graduates, which falls short of the increasing demand in the environmental industry. Particularly in the waste resource-to-energy field, there is a need for training human resources who will adapt to the transition to new energy methods, moving away from the existing methods such as simple disposal of waste, and play the main role in technology development. Therefore, the Ministry of Environment aims to produce 250 experts every year, such as having designated and operated five specialized graduate schools including flammable waste to energy and organic waste to energy, and practice-oriented and on-the-job training courses for employees in the industry since 2009. By 2017, it produced 3,772 tailored high-quality human resources in the waste resource-to-energy field.

(Education Training for International Environment Experts) The Ministry of Environment has operated training courses for international environment experts with Korea Environment Corporation since 2009 to respond to environmental issues, such as climate change and international environmental regulations, which have emerged as major international issues, and trained experts who will lead domestic and foreign environmental fields. The training target people receive professional training for four weeks on general environmental education, environmental policy and evaluation techniques, environmental issues and policies, etc., by sector, the graduates are offered opportunities to work as an intern at international environmental organizations located at home and abroad, including GGGI, UNEP, UNESCAP and UNESCO.

– Information Disclosure and Promotion

1) Campaign

(Energy Saving Campaign) The ROK's energy-saving campaign is carried out as a daily life-oriented program in which all citizens directly participate in initiating energy-saving practices. Among other things, the ROK has conducted contests and awarded prizes in continuing effort to expand the distribution of new and renewable energy, promote the new energy industry, and raise public awareness as well as induce and promote energy-saving practices through the Energy Contents Contest and New & Renewable Energy 36.5℃.

〈Table 6-5〉 Results of Energy Contents Contest and New & Renewable Energy 36.5℃

Campaign	Classification	2013	2014	2015	2016	2017
Total	Submitted	2,308	2,131	2,099	1,019	1,573
	Prize-winner	95	101	72	61	62
Energy-saving works	Number of contests	35	36	37	38	39
	Submitted	1,948	1,429	1,410	577	1,199
		87	84	55	44	36
New & Renewable Energy 36.5℃	Number of contests	2	3	4	5	6
	Submitted	360	702	689	442	347
	Prize-winner	8	17	17	17	26

※ Source: 2018 KEA Energy Handbook, Korea Energy Agency, 2018

Public relations cooperation projects with citizens include cooperation with private organizations and cooperation with the Korea NGO's Energy Network. NGOs are promoting energy-saving cooperation projects using NGO networks to promote a nationwide greenhouse gas reduction and energy-saving culture. The Korea NGO's Energy Network formed in 2000 around 260 civic groups across society, including consumers, women, and the environment, to induce voluntary energy-saving campaign of civil society.

〈Table 6-6〉 Private Organization Cooperation Project Support Status

Description	2013	2014	2015	2016	2017	2018	Total
Organizations/ Projects	24/24	24/24	24/24	18/18	20/20	21/21	212/216
Amount of support (million KRW)	330	330	328	252	252	232	3,345

※ Source: 2018 KEA Energy Handbook, Korea Energy Agency, 2018

The Korea Energy Agency is in charge of producing and distributing energy-saving promotional materials and strives to spread awareness of energy saving and to establish an energy-saving culture in daily life in preparation for the electric power demand crisis.

〈Table 6-7〉 Results of Energy Saving Promotional Materials Production and Distribution

Description		Quantity
Energy-saving promotional stickers	4 kinds of appropriate heating and cooling (public and private)	209,000 copies
	2 kinds of saving power and water	207,500 copies
Energy-saving posters during summer	Single poster	3,500 copies
Energy-saving posters during winter	Single poster	5,500 copies

※ Source: 2018 KEA Energy Handbook, Korea Energy Agency, 2018

(Low Carbon Green Life Action Campaign) The Low Carbon Green Life Action Campaign is a voluntary national campaign to reduce GHG emissions from non-industrial sectors such as residential, businesses, and transportation to respond to climate change. The Green Start National Network was changed to the Korea Climate & Environment Network on March 2014 to rapidly advance the practice campaign, which is implementing the Campaign to Reduce Greenhouse Gases in Everyday Life based on its vision of the Realization of Low Carbon, Eco-friendly Society with the People.

The Ministry of Environment is carrying out customized public relations and campaigns by time and target in cooperation with the Korea Climate & Environment Network to raise awareness of climate change and to induce low carbon life practices for all people. To maximize public interest and participation, the Ministry designated the Climate Change Week and launched the Low Carbon Holiday campaign during the week before and after Earth Day (April 22) and performed the Dress Cool and Dress Warm campaign to save energy in winter and summer, when demand for electricity is high.

(Environment Day Events) The ROK designated World Environment Day, June 5, as the statutory anniversary, Environment Day, in 1996 and organizes environmental conservation events nationwide every year, including the government memorial ceremony. It also makes efforts to raise public awareness of environmental conservation, such as designating every June as Environment Month and promoting various events related to the environment.

The ROK promoted environmental policy by operating exhibitions and an experience booth on renewable energy, resource circulation, chemical accidents, biological resources, environmental education, etc., with environmental conservation merit awards at the Official Ceremony for the 22nd Environment Day, held under the theme of Korea Where Life and Environment Values Live at KINTEX, Goyang, Gyeonggi-do on June 5, 2017. In conjunction with the Environment Day, it held the 39th International Exhibition on Environmental Technology and Green Energy at COEX, Seoul for three days to promote the expansion of domestic environmental companies in overseas and domestic markets.

(Green Card System) In July 2011, the Ministry of Environment introduced a green card system which allows users to earn points when purchasing low-carbon and eco-friendly products and using public transportation and then, receive discount services at tourism, cultural, and sports facilities of public institutions such as local governments to reduce GHG emissions in the private sector. The economic incentive for practicing green life practices is about KRW 200,000 per year.

20 financial institutions, 236 companies (2,419 products), and 784 public facilities participated in providing the incentives, which reduced CO_2 by 3.43 million tons CO_2eq. In November 2016, Green Card v2 was launched, becoming a representative eco-friendly financial product.

2) Climate Information Website of the Korea Meteorological Administration

The Climate Information Website is an Internet-based climate change information system to help the public understand the climate change science information based on data on domestic and foreign climate change information websites and provide conditions for relevant institutions to make extensive use of climate change research results. The system is designed to provide the integrated scientific information needed to develop climate change response measures and meet the people's right to know by disseminating easily understandable information on climate change.

3) Operation of Environmental Information Disclosure System

The environmental information disclosure system was introduced to establish a foundation for eco-friendly management throughout society and construct an autonomous environmental management system by enhancing the company's willingness to promote eco-friendly management through environmental information and the vitalization of environmental communication with the public. This system allows companies, etc., to self-diagnose the current status of environmental management and derive improvements by systematically managing and disclosing their environmental information. Also, the disclosed environmental information has the effect of strengthening the market monitoring function of companies' environmental management levels.

Currently, institutions subject to environmental information disclosure include central administrative agencies, local governments, public institutions (partly), national and public universities, local public corporations and agencies (partly), local medical centers (partly), green companies, and companies with high environmental impact (companies to which GHG allowances are allocated and GHG and energy target management companies). The target institutions are reclassified into six fields according to the inherent characteristics of the institutions, and the disclosed items on environmental information are differentiated.

4) Forest Education Center

The center, which is designated and organized to foster creativity and emotion of the people and to promote the values of forests, provides forest education to the public and develops and distributes textbooks and programs on forest education. The designation of forest education centers is limited to educational institutions belonging to national or local governments, universities in the field of forests, nonprofit corporations established with the permission of the Korea Forest Service or local governments, and arboretums. The designation criteria are more stringent than for an experience park for preschoolers; a center candidate must own or lease over 100,000㎡ of forest land and have lecture rooms, indoor training rooms, and a library. Eleven centers have been established in Honam, Yeongnam, Chungcheong, and Gangwon areas as of 2018.

5) Korea Climate & Environment Network

The Korea Climate & Environment Network is a governance body to reduce GHG emissions in the non-industrial sector through public-private cooperation, in which 52 organizations including public service, institutions, companies, and private organizations are participating, and there are 245 regional networks nationwide mainly around local governments and regional organizations. Its major projects include the pledge of practice to reduce 1 ton CO_2eq. per capita and the support of the project, and it distributes Green Touch and Green Printer programs as well as awarding best practices through events, campaigns, and contests. In addition, it offers additional benefits in combination with carbon points, Self Carfree days, and green transportation points.

4.2 Civic Group Activities

As environmental problems become an important issue in the ROK, civic groups play an important role in spreading social awareness of the climate change crisis and the importance of proactive responses. The number of environmental groups is increasing, and environmental groups, which work in their exclusive sectors and specialized areas, are also increasing.

The Korea NGO's Energy Network carries out various activities in cooperation with 222 member organizations nationwide to realize a low energy and sustainable society, such as energy saving campaign, education on energy and climate change, survey on squandering energy, search for response measures to climate change agreements, diffusion of energy-saving and energy-efficiency products, production of energy-related policies, and improvement of laws and systems.

The Biodiversity Foundation supports research in environmental studies and based on it, carries out projects aimed at the research, development,

survey, education, and the dissemination of natural environment and cultural contents pursuant to the provisions of the Act on the Establishment and Operation of Public Interest Corporations to contribute to the interests of the general public.

The Korean Federation for Environmental Movement conducts environmental pollution and ecosystem destruction prevention, environmental education and public relations for citizens, survey and research on environmental issues, policy suggestion projects, etc., to cope with the dangers of environmental pollution.

The Youth Climate Action, which consists of teenagers 13 years of age and older, prepares a lawsuit calling for government measures to address climate change issues such as heat and cold waves, fine dust, etc. The action is raised in the view that the damage caused by environmental problems violates the rights to environmental equality for future generations.

In addition, energy-related civic groups make efforts to overcome the energy crisis such as the depletion of energy sources, climate change, and environmental pollution. They are carrying out education and cultural projects to change public awareness, policy proposal projects that monitor government policy and suggest alternatives, campaigns, and energy-saving pilot projects to promote energy saving, renewable energy pilot projects to publicize the availability of renewable energy such as wind and solar power. Moreover, they join international environmental organizations and are engaged in global solidarity activities.

Appendix

1. Abbreviations
2. Publication Information

1. Abbreviations

AMI	Advanced Meteorological Imager
BAU	Business-As-Usual
BEMS	Building Energy Management System
BM	Benchmark
BRT	Bus Rapid Transit
CCS	Carbon Capture and Storage
CDM	Clean Development Mechanism
CO_2eq.	Carbon dioxide equivalent
CRAS	Climate change Risk Assessment System
DAC	Development Assistance Committee
EDCF	Economic Development Cooperation Fund
EnMS	Energy Management System
EPR	Extended Producer Responsibility
GAW	Global Atmosphere Watch
GDP	Gross Domestic Product
GF	Grandfathering
GFCS	Global Framework for Climate Services
GGGI	Global Green Growth Institute
GNI	Gross National Income
GWP	Global Warming Potential
IMO	International Maritime Organization
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
KAU	Korean Allowance Unit
KCU	Korean Credit Unit

KOC	Korean Offset Credit
KOOFS	Korea Ocean Observing and Forecasting System
LULUCF	Land Use, Land-Use Change and Forestry
MOPAN	Multilateral Organization Performance Assessment Network
NDC	Nationally Determined Contributions
NDE	National Designated Entity
NOAA	National Oceanic and Atmospheric Administration
ODA	Official Development Assistance
RCP	Representative Concentration Pathways
REDD+	Reducing Emissions from Deforestation and forest Degradation
RFS	Renewable Fuel Standard
RPS	Renewable Energy Portfolio Standard
SRF	Solid Refuse Fuel
TOE	Ton of Oil Equivalent
UNEP	United Nations Environment Programme
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNESCO	United Nations Educational, Scientific and Cultural Organization
VESTAP	Vulnerability Assessment Tool to build Climate Change Adaptation Plan
WCC	World Calibration Center
WFK	World Friends Korea
WMO	World Meteorological Organization

2. Publication Information

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