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Key Trends in Korean Government Spending on International Cooperative R&D for Carbon Neutrality

: Focusing on national R&D projects in mitigation

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C O N T E N T S

Chapter	1	Introduction	2
		1.1 Intensifying Global Competition in Technologies for Carbon Neutrality	2
		1.2 Necessity of Discussions for International Cooperation in Science and Technology for Carbon Neutrality	6
		1.3 Purpose and Scope	7
Chapter	2	Investment Trends in Carbon Neutrality International Cooperation R&D	12
Chapter	3	Cooperation Trends in Carbon Neutrality International Cooperation R&D	20
		3.1 Cooperation Types of Carbon Neutrality International Cooperation R&D	20
		3.2 Status of Jointly Commissioned Research with Foreign Countries/Institutions in Carbon Neutrality International Cooperation R&D	23
Chapter	4	Implications	25
		4.1 Strategy Development and Investment Expansion for Carbon Neutrality International Cooperation R&D	25
		4.2 Diversification of Cooperation Types and Partner Countries in Carbon Neutrality International Cooperation R&D	26

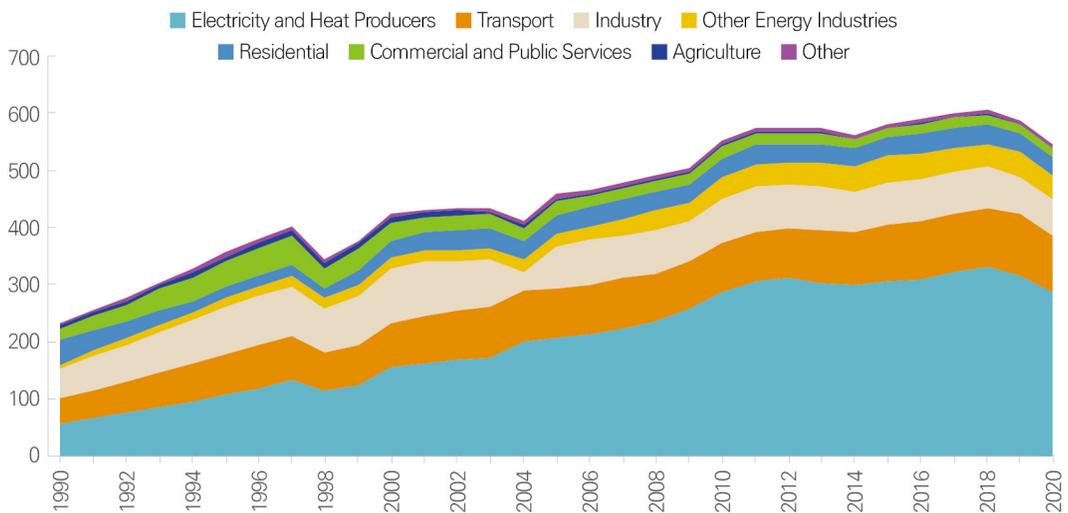
Chapter 1

Introduction

1.1 Intensifying Global Competition in Technologies for Carbon Neutrality

- In response to the growing call for a transnational action to global climate crisis, the Republic of Korea has actively pursued efforts in reducing greenhouse gas emissions through relative policies and R&D investment strategies in the field of carbon neutrality.
- In Korea, the level of greenhouse gas emissions from energy has steadily increased over the past 30 years, reaching its peak at 605.Mt in 2018. Though emissions had decreased until 2020, they rebounded again in 2021 to reach 581.94Mt (IEA, 2023).
 - When examined in share by sector, production and fuel consumption mainly from power generation, transport, and industrial sectors account for the majority of the emissions.

[Figure 1-1] Greenhouse Gas Emission Trends in Korea (Mt of CO2, 1990–2020)



※ Source: IEA Greenhouse Gas Emissions from Energy (April 2023)

- Through *The 1st National Basic Plan for Carbon Neutrality and Green Growth* (April 2023), Korea announced the yearly and sector-specific reduction goals, detailed implementation tasks, and execution measures to achieve its 2030 Nationally Determined Contributions (NDCs), 40% reduction compared to emission levels in 2018.
- Against this backdrop, in addition to expanding R&D investments for achieving carbon neutrality by 2050, there is a need to simultaneously consider how the effectiveness and efficiency of the R&D initiatives can be enhanced.

○ Amid the rapid growth of the carbon neutral technology market, along with the increasing global response to combat climate change and to reduce emissions, attempts to introduce trade barriers have emerged among advanced countries, thereby emphasizing the importance of securing technological leadership.

- As the need for climate change response increases, the climate technology market is expected to maintain a steep growth trajectory (KOTRA, 2022).
 - The global climate technology market was valued at USD 13 billion in 2021, recording an average annual growth rate of 17.5% from 2017 to 2021.
 - Market size estimates project a nine-fold increase in its growth from USD 16.9 billion in 2022 to USD 147.5 billion in 2032, expecting an average annual growth rate of 24.2% over the next decade.
- Recently, a trend of strengthened protectionism has emerged, primarily led by advanced countries, through the introduction of Technical Barriers to Trade (TBTs)*, whose application has extended to the environmental sector, thus intensifying the attempts to combine environmental and trade policies.

* Refers to trade barriers caused by differences in technical regulations, standards, and conformity assessment procedures between countries. Under the World Trade Organization (WTO) TBT Agreement, when countries enact or revise related regulations and procedures that have a significant impact on trade, they are obligated to notify the WTO.

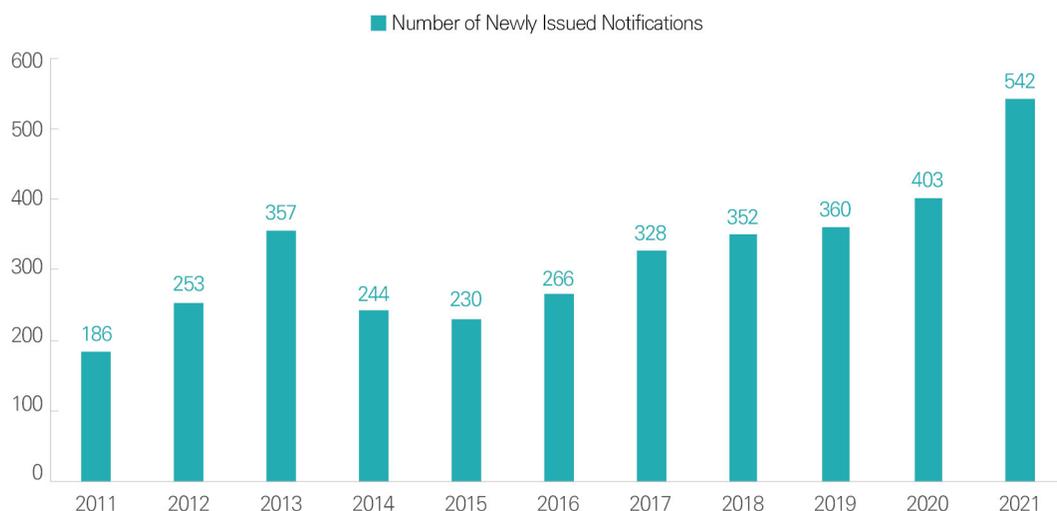
– A representative example of this is the introduction of the Carbon Border Adjustment Mechanism (CBAM)* by the European Union (EU), in which emission calculations for six sectors (steel, aluminum, cement, fertilizers, electricity, and hydrogen) served as a basis for the implementation of mandatory CBAM certificate purchases from 2026, with a transition period from October 2023.

* Refers to a trade restriction measure aimed at correcting differences in countries' efforts and willingness to reduce greenhouse gas emissions.

– The number of TBT notifications for environmental protection purposes (in the fields of energy efficiency, waste/recycling, and chemical substances) and the number of newly raised Specific Trade Concerns (STCs)* related to such TBTs have also continued to increase.

* Refers to concerns raised by WTO members in official meetings regarding TBT-related measures taken by other member countries.

[Figure 1-2] New Issuance of TBT Notifications for Environmental Protection Purposes
(Number of Issuance Cases)



※ Source: Korea Agency for Technology and Standards (2022)

● In addition, given the strengthening of technology alliances among technologically advanced countries due to the increasing competition for technological hegemony between the United States and China, the new “Tech Cold War”, measures and strategies are needed to overcome the rising carbon trade barriers and to prevent isolation from the heightened technology competition.

- Rapid economic and technological securitization, driven by factors such as climate change and the global pandemic, have led to the rise of the concept of ‘Technology Sovereignty’*, as well as to new scientific cooperation and technological alliance systems.

* Refers to the ability of a state to directly develop or procure technologies that are indispensable for maintaining its own welfare and competitiveness without a unilateral dependence on other countries (Edler et al., 2020).

- Through the United States Innovation and Competition Act of 2021 (USICA), the U.S. government has specified its plans for investing in science, technology, and innovation, as well as for expanding cooperation with ally countries and strengthening international collaboration to counter and compete with China.

– Measures have been taken to enhance technological cooperation with allied countries including the establishment of and budget allocation for the Technology Partnerships Office within the Department of State, the launch of the US–EU Trade and Technology Council (TTC), and the operation of the Quadilateral Security Dialogue (QUAD)*.

* Refers to the strategic security dialogue between the U.S., Japan, India, and Australia.

- The EU has adopted the Team Europe approach, pursuing multilateral cooperation and international collaboration in research and innovation to secure technology sovereignty and address climate change through its leadership in the twin green & digital transition.
 - While strategically engaging in pragmatic diplomacy, the EU is actively building close mini-lateral partnerships with other technologically advanced nations and leveraging the ‘Horizon Europe’ research and innovation program as a vehicle to implement its strategy.

○ Given this context, where it is necessary to improve the technological capabilities in the field of carbon neutrality in Korea, international cooperation with leading nations is an essential element to secure national competitiveness and to target global markets.

- As the trend of international protectionism, climate change response, and environmental protection continues to strengthen, technologically advanced nations are actively utilizing various means of international cooperation, including scientific and technological collaborations and Official Development Assistance (ODA) to better seize opportunities in the emerging carbon neutral technology market.
- Furthermore, as the technology level is still relatively low compared to other technologically advanced nations, international cooperation in carbon neutral science and technology is essential for Korea to elevate its technological capabilities.
 - According to an evaluation* on technological level in climate mitigation field, among the five major countries (Korea, China, Japan, U.S., and EU), Korea is categorized under the ‘Following Country Group**’, at a technology level of 80% and with a technology gap of three years relative to the United States and EU which have been evaluated as countries equipped with the highest technology levels in the said field.

* Based on a comprehensive analysis of quantitative data (e.g. papers and patents in climate technology) and qualitative data collected via Expert Delphi survey method (National Institute of Green Technology, 2020).

** Leading Country Group: U.S. and EU / Following Country Group: Japan, Korea, China

- In terms of research capacity, for both basic and applied/development research, Korea ranks in 4th, after the U.S., the EU, Japan, and China.

[Table 1–1] Technology Level, Technology Gap, and Research Capacity by Country in Climate Mitigation Technology

Category		Korea	China	Japan	US	EU
Technology Level (%)		80	80	90	100	100
Technology Gap (Years)		3	3.5	1.5	0	0
Research Capacity (Score)	Basic	68.5	66.3	82.6	90.7	89.8
	Applied / Development	71.8	68.3	79.1	88.0	87.2

※ Source: National Institute for Green Technology (2020)

1.2 Necessity of Discussions for International Cooperation in Science and Technology for Carbon Neutrality

● The Korean government has recently recognized the importance of international cooperation in carbon neutral science and technology and that the demand on policies for setting directions and establishing systems for technological cooperation with technologically advanced nations has increased.

- *The 1st Mid-to-Long-Term National R&D Investment Strategy 2023–2027* (March 2023)* is the first legislated mid-to-long-term investment strategy of the national R&D budget. It emphasizes an active investment in the development of 12 national strategic technologies and the implementation of carbon neutrality (including energy technology innovation and the transition to a low-carbon industrial structure), as well as specifies international cooperation strategies, to achieve the goal of becoming one of the world's top five leading nations in science and technology by 2030.

* First statutory national R&D budget plan and top-level investment strategy established under Yoon Suk-yeol administration, outlining strategic investment objectives and directions for national R&D budget over the next five years.

- Includes measures to reinforce the strategic nature of international cooperation and joint research in science and technology in pursuit of global sustainable development.
- In the *Investment Direction and Standard for National R&D of 2023 (Draft)* (March 2022), the government outlined its objective of promoting large-scale R&D focused on supporting technology innovation and strengthening the industrial ecosystem to respond to global issues related to carbon neutrality and transition.
 - Among the nine areas of focus, international cooperation (global manpower exchange and ODA-linked cooperation) is included along with carbon neutrality (establishment of the necessary foundation for carbon neutrality, such as low-carbon energy and green transition).
- Through the *Carbon Neutrality and Green Growth Promotion Strategy* and *Carbon Neutrality and Green Growth Technology Innovation Strategy* (October 2022), the 2050 Carbon Neutrality and Green Growth Commission presented a series of strategies including the enhancement of solidarity for climate action through bilateral and multilateral cooperation, reinforcement of strategic international cooperation centered on advanced nations, and promotion of international cooperation flagship projects that are linked to empirical evidence.
- The Ministry of Science and ICT (MSIT) formed the 'Carbon Neutrality International Cooperation Public-Private Task Force Team' in November 2022, consisting of experts from the industry and academia. The task force initiated discussions on the direction of technological cooperation and confirmed the need for customized and strategic partner countries and institutions through an analysis of competitiveness by the type of carbon neutral technology.
 - It emphasized the need to enhance the efficiency and effectiveness of R&D investments by strategically setting the direction of technological cooperation with key partner countries.

- Although the government has presented a direction to strengthen international cooperation in the field of carbon neutrality, there is still a lack of discussion regarding specific implementation and investment strategies, as well as of an analysis on the current status of R&D, which are necessary to provide a basis for the said discussions.

1.3 Purpose and Scope

- This Focus aims to conduct research and analysis on the R&D investment status and cooperation trends in international cooperation for science and technology in the field of carbon neutrality in order to provide insights and implications for securing greater technological competitiveness.
- The dataset for analysis was extracted and built based on the climate technology national R&D project data from the past five years (2017–2021).
 - The subject of analysis was based on the national R&D project* information provided by the National Science and Technology Information Service (NTIS), from which the final unit of analysis was set as the individual projects executed through R&D programs within the budget system.
 - * Refers R&D projects classified under the R&D budget and pursued through government funds within the government budget (general accounts + special accounts).
 - The projects for analysis were extracted from the *Analytical Report on Climate Technology National R&D* published by the National Institute of Green Technology (NIGT, formerly the Green Technology Center Korea), which collected and analyzed information on government spending on climate technology R&D.
 - Among the NTIS national R&D projects, programs and sub-projects corresponding to the 45 major technologies* identified in the ‘Climate Technology Classification System’ (NIGT, 2017)** were included, encompassing three major categories: 1) mitigation¹⁾, 2) adaptation²⁾, and 3) mitigation/adaptation convergence (Multi-Sector)³⁾
 - * MSIT (December 2017), “Notification of the Establishment of the Climate Technology Classification System (Draft) to Promote Global Climate Technology Cooperation”
 - ** Climate technology is divided into 3 major categories, 14 divisions, and 45 sections.

1) Human interventions to reduce the use of resources or enhance the sinks of greenhouse gases (IPCC, 2012)

2) Process of adjustment to actual or expected climate and its effects (IPCC, 2012)

3) Actions that contribute to greenhouse gas mitigation and prevent climate change induced damage, and the convergence and combined use of multiple mitigation and adaptation technologies (Green Technology Center, 2022)

① (Carbon Neutrality) Programs and sub-projects that correspond to mitigation and/or mitigation/adaptation convergence categories within the research scope of climate technology national R&D projects.

- In this Focus, the scope of analysis was limited to the carbon neutrality sector to select programs and projects* from the climate technology national R&D projects that correspond to mitigation and/or mitigation/adaptation convergence categories only (excluding adaptation category), which are highly relevant to de-carbonization transition efforts for achieving carbon neutrality.

* (2017–2021) 886 programs and 31,997 sub-projects

[Table 1–2] Scope of Analysis for National R&D Projects in the Carbon Neutrality Sector

Category	Division	Section
Mitigation	Greenhouse Gas Mitigation	Non-Renewable Energy Nuclear Power, Nuclear Fusion Power, Clean Thermal Power & Efficiency
		Renewable Energy Hydropower, Photovoltaic Power, Solar Heat, Geothermal Power, Wind Power, Ocean Energy, Bio Energy, Waste
		New Energy Hydrogen Manufacturing, Fuel Cell
		Energy Storage Power Storage, Hydrogen Storage
		Transmission / Distribution / Power IT Transmission & Distribution System, Intelligent Electric Device
		Energy Demand Transport Efficiency, Industrial Efficiency, Building Efficiency
	Greenhouse Gas Sequestration	CCUS, Non-CO ₂ Mitigation
Mitigation / Adaptation Convergence (Multi-Sector)	Mixture of Multiple Areas	New and Renewable Energy Hybrid, Low Power Consumption Equipment, Energy Harvesting, Artificial Photosynthesis, Other Technologies Related to Climate Change

※ Source: Climate Technology Classification (National Institute for Green Technology, 2017)

② (International Cooperation) Programs and sub-projects of which the purpose of support within the national R&D budget corresponds to ‘international cooperation’.

- Referring to the *Comprehensive Guide to National R&D Projects*, which provides comprehensive information related to national R&D projects, programs and projects whose purpose of support includes ‘international cooperation’ were selected as the analysis target.

* Purposes of support in the national R&D budget include industrial technology development, systems establishment, human resource development, etc.

[Table 1–3] An Example of Provided Information in *Comprehensive Guide to National R&D Projects*

Ministry	Ministry of Science and ICT (MSIT)
Project Name	Foundation Establishment for International Cooperation in Nuclear Power
Area / Field of Support	Nuclear Power
Research Entity	University, Research Institutes, Corporations
Purpose of Support	International Cooperation, R&D
Stage of Development	Basic Research, Others
Duration of Research & Development (Months)	6–60
Size of Government Investment in 2021 (KRW 100 million)	69.56
Average Size per Project in 2021 (KRW million)	409
Expected Date of Announcement for New Projects in 2021	February, May

※ Source: Comprehensive Guide to National R&D Projects 2021 (Korea Council of R&D Funding Agencies, 2021)

- From the climate technology national R&D projects, this Focus will: 1) select programs and sub-projects relative to mitigation (referred to as ‘carbon neutrality R&D’), 2) specify programs and sub-projects whose purpose of support corresponds to international cooperation (referred to as ‘carbon neutrality international cooperation R&D’), and 3) conduct analysis on the investment and cooperation trends in so-called carbon neutrality international cooperation national R&D projects.
 - The final dataset for the analysis includes 15 programs, 753 sub-projects.

[Table 1–4] Carbon Neutrality International Cooperation National R&D Projects included in Analysis

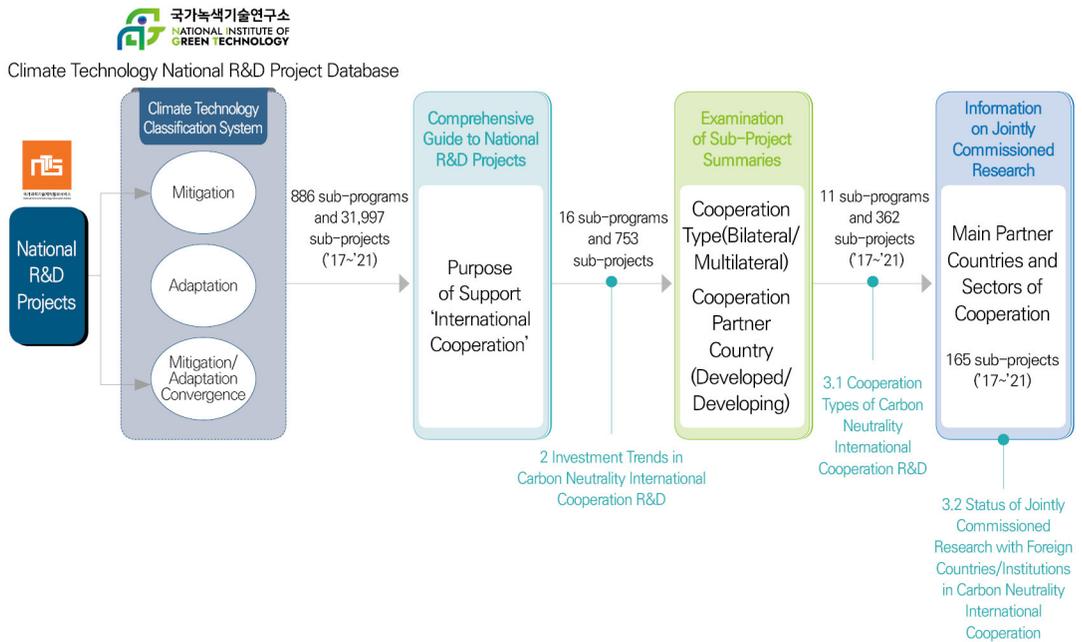
Ministry	Project Name
Ministry of Science and ICT	<ul style="list-style-type: none"> • Program to Develop the Foundation for International Cooperation • International Climate Technology Cooperation Program (ODA) • Program to Establish R&D Hub in Northeast Asia • International Space Cooperation Program • International Nuclear Cooperation Program • Program to Support Group Research (Support for Global Labs) • Global R&D Center (GRDC) • Program to Develop Cooperation Hubs with Overseas Research Institutes of Excellence
Ministry of Education	<ul style="list-style-type: none"> • Global Research Network Program (GRN)
Ministry of Land, Infrastructure, and Transport	<ul style="list-style-type: none"> • Research to Promote Land, Infrastructure, and Transport Technologies
Ministry of Health and Welfare	<ul style="list-style-type: none"> • Program for Development of Leading Technologies in Korean Oriental Medicine
Korea Forest Service	<ul style="list-style-type: none"> • Research on New Climate Regime Response
Ministry of Trade, Industry, and Energy	<ul style="list-style-type: none"> • Civil–Military Technology Cooperation • International Cooperation in Industrial Technology • International Joint Research in Energy

- Additionally, the current status of foreign countries' participation in those R&D joint research projects will be investigated by utilizing information on whether the projects have been jointly commissioned for research.*

* Joint Commission Information from NTIS (2017–2021)

– 4 programs and 165 sub-projects qualify for additional analysis.

[Figure 1-3] Data Extraction Process for the Analysis on the Current Status and Trends in Carbon Neutrality International Cooperation R&D



※ Created by the authors.

Chapter 2

Investment Trends in Carbon Neutrality International Cooperation R&D

● In the last five years (2017–2021), the government’s investment in carbon neutrality R&D projects amounted to approximately KRW 10.27 trillion, accounting for 9.3% of country’s total R&D projects during the period.

- The government’s research funds for carbon neutrality R&D projects showed the following trend: KRW 1.86 trillion in 2017, KRW 1.85 trillion in 2018, KRW 1.89 trillion in 2019, KRW 2.19 trillion in 2020, and KRW 2.47 trillion in 2021, reaching a compound annual growth rate (CAGR) of 5.8% for this period.

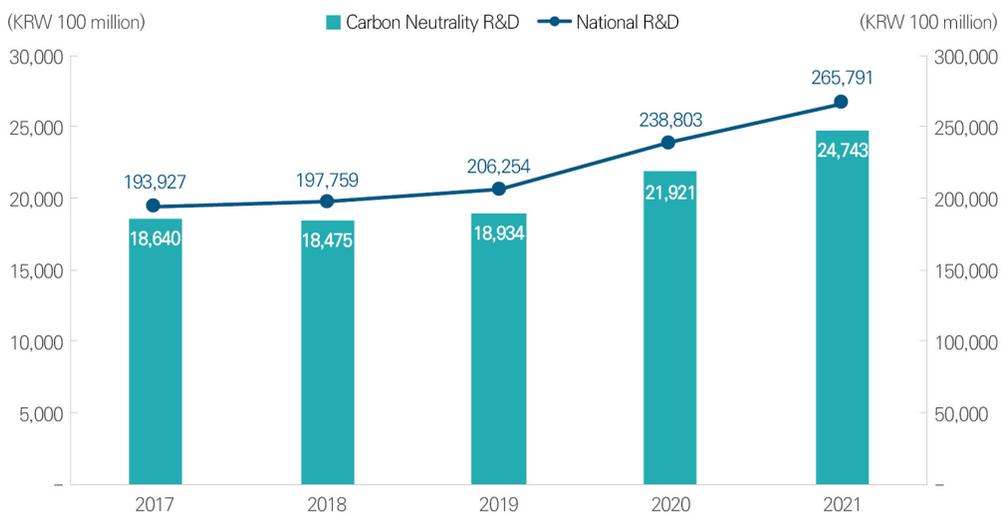
- Before 2020, the year-on-year growth rate of carbon neutrality R&D projects* recorded a lower growth rate compared to that of national R&D projects**. However, from 2020, it recorded similar or higher growth rates.

* (2017) 0.8% ↑ → (2018) 0.9% ↓ → (2019) 2.5% ↑ → (2020) 15.8% ↑ → (2021) 12.9% ↑

** (2017) 2.0% ↑ → (2018) 2.0% ↑ → (2019) 4.3% ↑ → (2020) 15.8% ↑ → (2021) 11.3% ↑, CAGR 6.5%

- The proportion of carbon neutrality R&D projects relative to the national R&D projects has remained consistent over the years: 9.6% in 2017, 9.3% in 2018, 9.2% in 2019, 9.2% in 2020, and 9.3% in 2021.

[Figure 2-1] Comparison in Size of Carbon Neutrality R&D Projects and National R&D Projects (KRW 100 million, %, 2017–2021)



※ Source: Recreated by the authors with data from 2017–2021

「Analytical Report on Climate Technology National R&D」(National Institute for Green Technology, 2018–2022)

Supplementary

- By sector, energy demand, non-renewable energy, and energy storage take a high proportion, while new energy and greenhouse gas sequestration show a high growth rate.

[Supplementary 1] Carbon Neutrality R&D Project Status by Year and Sector
(KRW 100 million, 2017–2021)

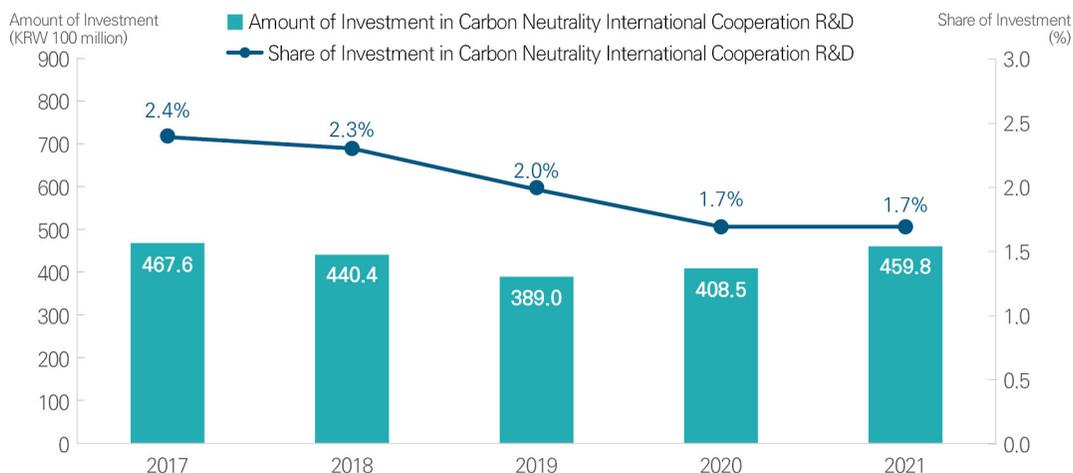
	2017	2018	2019	2020	2021
Carbon Neutrality	18,640	18,475	18,934	21,921	24,743
Non-Renewable Energy	3,941	3,849	3,847	4,342	4,460
Renewable Energy	3,156	3,404	3,469	3,771	3,746
New Energy	1,010	768	1,034	1,704	2,544
Energy Storage	1,989	1,943	2,003	2,886	4,001
Transmission / Distribution / Power IT	718	761	1,088	1,412	1,537
Energy Demand	5,579	5,544	5,579	5,776	5,836
Greenhouse Gas Sequestration	764	617	784	823	1,228
Mitigation / Adaptation Convergence (Multi-Sector)	1,534	1,590	1,131	1,308	1,390

※ Source: Recreated by the authors with data from 2017–2021

† Analytical Report on Climate Technology National R&D (National Institute for Green Technology, 2018–2022)

- In the last five years (2017–2021), the government’s investment in carbon neutrality international cooperation R&D projects amounted to approximately KRW 216.5 billion, which accounts for only less than 2% of the carbon neutrality R&D projects and also has a relatively small size of average government research budget per project.

[Figure 2-2] Size and Share of Carbon Neutrality International Cooperation R&D Projects (KRW 100 million, %, 2017-2021)



※ Created by the authors.

- The size of government’s research funds for carbon neutrality international cooperation R&D projects showed the following trend: KRW 46.76 billion in 2017, KRW 44.04 billion in 2018, KRW 38.90 billion in 2019, KRW 40.85 billion in 2020, and KRW 45.98 billion in 2021, resulting in a CAGR of -0.3% during this period.

* Year-on-year growth rates: (2018) 5.8% ↓ → (2019) 11.7% ↓ → (2020) 5.0% ↑ → (2021) 12.5% ↑

- The share of carbon neutrality international cooperation R&D projects relative to the total carbon neutrality R&D projects has steadily decreased over the years: 2.4% in 2017, 2.3% in 2018, 2.0% in 2019, 1.7% in 2020, and 1.7% in 2021*.

* As this share has declined since 2018, it is not considered attributable to the impact of the pandemic.

Supplementary

- During the period 2017–2021, the size of government’s investment in R&D projects with international cooperation objectives within the national R&D projects amounted to approximately KRW 3.08 trillion and the annual growth rate shows a similar tendency to that of carbon neutrality international cooperation R&D.
- The share of international cooperation R&D projects relative to the country’s total R&D projects showed the following trend: 3.8% in 2017, 2.9% in 2018, 2.5% in 2019, 2.2% in 2020, and 2.7% in 2021. As such, the overall share of international cooperation R&D investments declined but rebounded in 2021, whereas the share of carbon neutrality international cooperation R&D investments demonstrates a continued decline.

[Supplementary 2] Comparison of R&D Project Status (KRW 100 million, %, 2017–2021)

	2017	2018	2019	2020	2021
National R&D (A)	193,927 (2.0% ↑)	197,759 (2.0% ↑)	206,254 (4.3% ↑)	238,803 (15.8% ↑)	265,791 (11.3% ↑)
International Cooperation R&D (B)	7,341	5,797 (21.0% ↓)	5,090 (12.2% ↓)	5,310 (4.3% ↑)	7,269 (36.9% ↑)
(B/A)(%)	3.8	2.9	2.5	2.2	2.7
Carbon Neutrality R&D (C)	18,640 (0.8% ↑)	18,475 (0.9% ↓)	18,934 (2.5% ↑)	21,921 (15.8% ↑)	24,743 (11.3% ↑)
(C/A)(%)	9.6	9.3	9.2	9.2	9.3
Carbon Neutrality International Cooperation R&D (D)	468	440 (5.8% ↓)	389 (11.7% ↓)	409 (5.0% ↑)	460 (12.5% ↑)
(D/C)(%)	2.4	2.3	2.0	1.7	1.7

※ Created by the authors.

- Comparing the average government research funding per project, carbon neutrality R&D is at KRW 340 million per project and carbon neutrality international cooperation R&D is at KRW 290 million per project, showing a relatively small size per project as well.

○ Comparing and analyzing the government research funding size of the carbon neutrality R&D projects and carbon neutrality international cooperation R&D projects by the sector, entity, and stage, key trends in the current status of carbon neutrality science and technology international cooperation R&D can be identified.

- (By Sector) In carbon neutrality R&D projects, while a large share is taken up by energy demand (27.5%), non-renewable energy (19.4%), and energy storage (11.6%), in carbon neutrality international cooperation R&D projects, a large share is accounted for by energy demand (25.0%) and renewable energy (24.4%).
- Renewable energy appears to be a more active sector in the field of international cooperation.

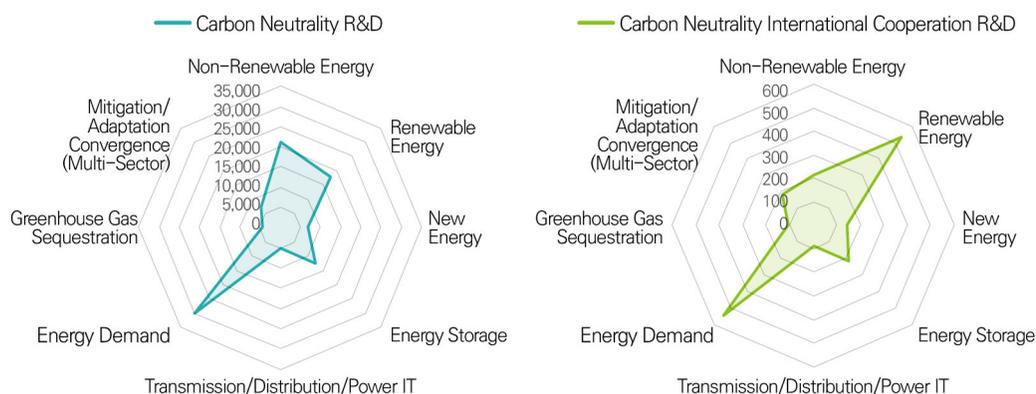
[Table 2-5] Size of Carbon Neutrality International Cooperation R&D Projects by Sector (KRW 100 million (%), 2017-2021)

By Sector	Non-Renewable Energy	Renewable Energy	New Energy	Energy Storage	Trans. / Distr. / Power IT	Energy Demand	Greenhouse Gas Seq.	Multi-Sector	Other*
Carbon Neutrality	21,224 (19.4)	17,703 (16.2)	6,906 (6.3)	12,625 (11.55)	5,281 (4.83)	30,062 (27.50)	4,195 (3.84)	6,878 (6.29)	4,461 (4.08)
Carbon Neutrality Int'l Cooperation	215 (9.92)	529 (24.43)	142 (6.55)	215 (9.93)	86 (3.99)	541 (24.98)	106 (4.9)	186 (8.57)	146 (6.74)

* Projects classified as 'Other' after excluding the Adaptation sector.

※ Created by the authors.

[Figure 2-3] Comparison between Carbon Neutrality R&D and Carbon Neutrality International Cooperation R&D by Sector (KRW 100 million, 2017-2021)



※ Created by the authors.

- (By Entity) In carbon neutrality R&D projects, while a large share is taken up by government-funded research institutes (GRIs) (31.6%) and small and medium-sized enterprises (SMEs) (30.7%), in carbon neutrality international cooperation R&D projects, a large share is accounted for by universities (35.5%)*, SMEs (29.4%), and GRIs (21.9%).

* In the country's international cooperation R&D projects, the participation from universities is also the most active: universities (52.6%), GRIs (18.5%), and SMEs (15.8%).

- (By Stage) In carbon neutrality R&D projects, while the largest share is taken up by development research (47.6%), in carbon neutrality international cooperation R&D projects, the largest share is accounted for by basic research (37.4%)*.

* In the country's international cooperation R&D projects, similar to carbon neutrality R&D, the shares are in the order of development research (36.6%), basic research (33.1%), and applied research (23.6%), thereby indicating that international cooperation R&D in the field of carbon neutrality is especially active in basic research.

**[Table 2-6] Size of Carbon Neutrality International Cooperation R&D by Entity and Sector
(KRW 100 million (%), 2017-2021)**

Entity	GRIs	University	Large Companies	Middle-Sized Companies	SMEs	Other*
Carbon Neutrality	34,538 (31.59)	18,720 (17.12)	6,268 (5.73)	6,431 (5.88)	33,533 (30.67)	9,843 (9.00)
Carbon Neutrality International Cooperation	473.9 (21.89)	768.7 (35.5)	106.1 (4.9)	33.0 (1.53)	636.5 (29.39)	147.2 (6.8)
Non-Renewable Energy	158.2	52.3	-	-	4.2	-
Renewable Energy	74.5	219.6	10.3	0.4	223.3	1.0
New Energy	98.1	19.7	0.9	-	23.0	-
Energy Storage	24.1	63.0	7.5	9.2	55.7	55.7
Transmission / Distribution / Power IT	2.3	29.7	5.0	-	49.4	-
Energy Demand	54.6	192.7	7.4	17.5	221.3	47.4
Greenhouse Gas Sequestration	20.3	85.8	-	-	-	-
Mitigation / Adaptation Convergence (Multi-Sector)	38.4	51.5	2.3	6.0	47.7	39.7
Other	3.5	54.3	72.7	-	11.9	3.4

* [Carbon Neutrality] Includes National/Public Research Institutes (KRW 56.9 billion), Government Ministries (KRW 400 million), Other (KRW 927 billion). [International Cooperation] Includes Government Ministries (KRW 400 million, Multi-Sector), Other (KRW 14.3 billion).

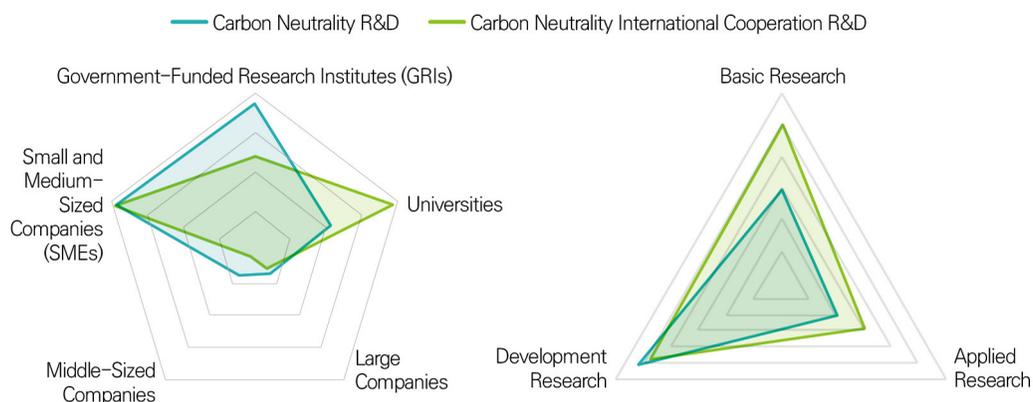
※ Created by the authors.

[Table 2-7] Size of Carbon Neutrality International Cooperation R&D Projects by Stage and Sector
(KRW 100 million (%), 2017-2021)

Stage	Basic Research	Applied Research	Development Research	Other
Carbon Neutrality	29,238 (26.74)	20,415 (18.67)	52,084 (47.64)	7,598 (6.95)
Carbon Neutrality International Cooperation	809.3 (37.38)	525.5 (24.27)	797.2 (36.82)	33.4 (1.54)
Non-Renewable Energy	208.2	6.6	-	-
Renewable Energy	136.8	159.4	220.9	12.0
New Energy	23.9	54.8	61.6	1.4
Energy Storage	64.5	82.4	68.2	-
Transmission / Distribution / Power IT	15.7	8.4	61.3	1.0
Energy Demand	152.3	140.6	233.1	14.8
Greenhouse Gas Sequestration	79.1	22.0	5.0	-
Mitigation / Adaptation Convergence (Multi-Sector)	77.8	30.8	72.8	4.2
Other	51.1	20.5	74.3	-

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[Figure 2-4] Comparison between Carbon Neutrality R&D and Carbon Neutrality International Cooperation R&D by Entity and Stage (2017-2021)



※ Created by the authors.

- From the comparison and analysis of carbon neutrality R&D projects and carbon neutrality international cooperation R&D projects, the results can be interpreted as that: in the overall field of carbon neutrality, 1) R&D in the renewable energy sector is primarily carried out through international cooperation, 2) the most active research entity in international cooperation is universities, and 3) international cooperation is mainly undertaken to conduct basic research.

Chapter 3

Cooperation Trends in Carbon Neutrality International Cooperation R&D

3.1 Cooperation Types of Carbon Neutrality International Cooperation R&D

● Based on a comprehensive examination of the project summaries provided by NTIS on a total of 753 sub-projects for carbon neutrality international cooperation R&D from the last five years (2017–2021) included in this analysis, the cooperation type – bilateral or multilateral – and partner country – developed or developing – was classified.

- Among all carbon neutrality R&D projects, those with a specified cooperation partner country or overseas research institution disclosed in the project summary were extracted to investigate cooperation trends. Such projects accounted for 362 projects out of the total (48%), of which the majority took the form of bilateral cooperation (347 projects, 96%).
- Major multilateral cooperation projects (4%) include the EU Horizon and projects that aim to develop/establish cooperative hubs with overseas research institutes of excellence.
 - In recent times, multilateral cooperation is becoming growingly important due to the rising need for unified responses and shared responsibility towards global issues, such as the pandemic, climate change, and conflicts. Particularly for Korea, given its membership in the group of advanced nations, multilateral cooperation is critical for it to lead efforts in contributing to the creation of global public goods and to secure competitiveness.
 - Introduced in 2021, the Program to Develop Cooperation Hubs with Overseas Research Institutes of Excellence is a global problem-solving and multilateral initiative that includes joint research sub-projects with newly established research institutes of excellence in developing countries. It is a network-oriented project that simultaneously advances the overseas expansion of domestic innovative capacities.
 - Particularly, in the case of sub-projects under joint research projects with overseas research institutes of excellence that are classified as ‘multilateral cooperation’ in this analysis, their aim is in securing basic and proprietary technologies and developing human resources through joint research between research institutes from developed and developing countries.

* ① KAIST (Korea Advanced Institute of Science & Technology)–UCB (University of California, Berkeley)–VNU (Vietnam National University) Global Climate Change Research Center, ② Korea–Denmark–Taiwan International Joint Research on High–Efficiency Eco–Friendly Material Process Development, ③ Korea–Australia–Kyoto University Joint Research on Environmental Sensing of Novel Anthropogenic Hazard Factors

[Figure 3-3] Status of Bilateral and Multilateral Cooperation Type in Carbon Neutrality International Cooperation R&D Projects by Year (% , Project Number, 2017-2021)



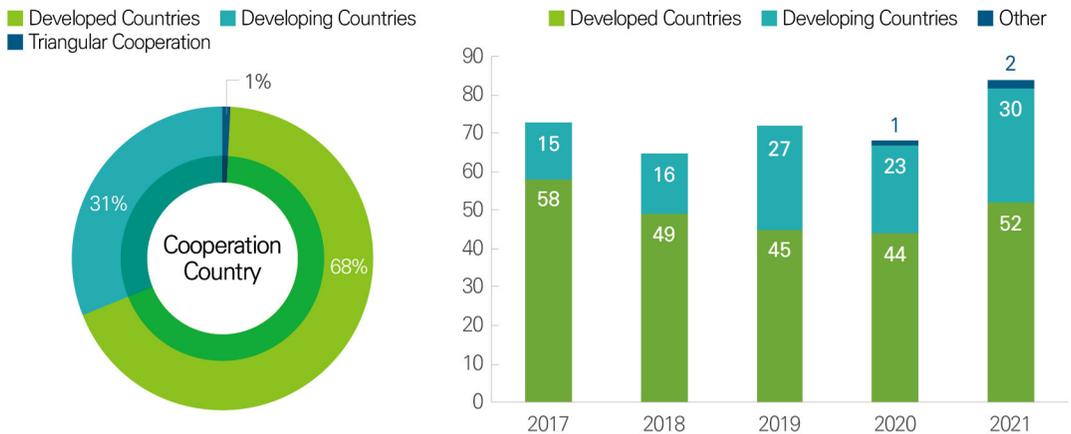
※ Created by the authors.

● **Developed countries account for 68% of the partner countries for international cooperation R&D**

- When cooperation partner countries are categorized by type, while developed countries take up 68% and developing countries take up 31%, cooperation with developing countries has recently expanded. Other forms of cooperation include triangular cooperation pursued through trust funds from international organizations* or cooperative hub development projects.

* UNFCCC CTCN Trust Fund for the creation of foundation/infrastructure for climate technology cooperation

[Figure 3-4] Status of Bilateral and Multilateral Cooperation Partner Country in Carbon Neutrality International Cooperation R&D Projects by Year (% , Project Number, 2017-2021)

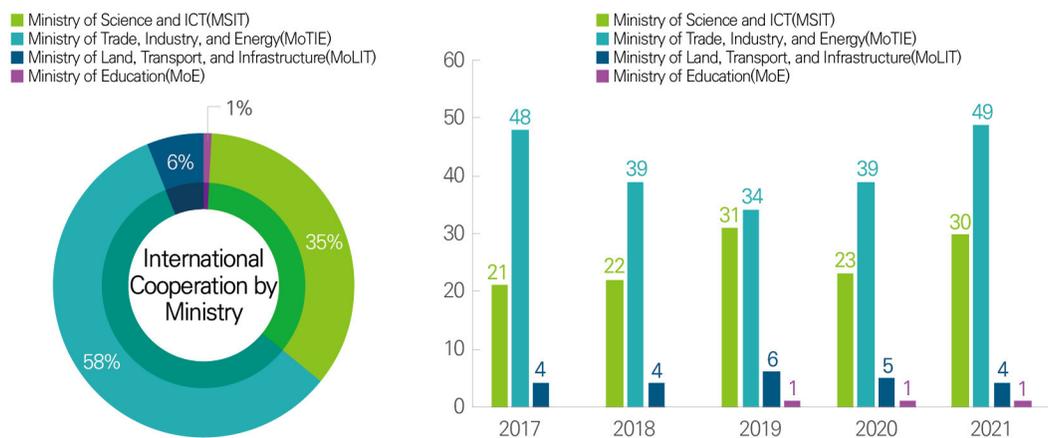


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Examining the current status of international cooperation by government department, the Ministry of Trade, Industry, and Energy (MOTIE) takes up the largest share (58%, 209 projects), followed by MSIT (35%, 127 projects), the Ministry of Land, Transport, and Maritime Affairs (MOLIT) (6%, 23 projects), and Ministry of Education (MOE) (1%, 3 projects). Among these, only the MOTIE and MSIT support multilateral cooperation projects.

- The MOTIE supports the largest-scale R&D projects through its international cooperation in industrial technology and joint research in energy. The MSIT supports international cooperation R&D through programs and projects that aim to create the infrastructure/ foundation for inter-governmental and international cooperation in (space) nuclear energy and climate technology, as well as through strategic international joint research programs and cooperative hubs with overseas research institutes of excellence.
 - Programs supported by MOTIE include: 1) Bilateral Joint Funding R&D, where a consortium is formed with institutions of the partner country as agreed upon by both governments and funding is provided to domestic institutions for projects that are jointly approved, 2) Multilateral Joint Funding R&D (such as EU Horizon), where a consortium is formed with participating countries in the multilateral R&D program and domestic funding is provided for projects approved by the relevant operating organization, and 3) Strategic Joint Technology Development Projects that promote diverse forms of technological cooperation with leading global and overseas institutions.
 - MSIT supports projects that create the infrastructure/foundation for inter-governmental cooperation are utilized to facilitate the early stages of cooperation and exchange with bilateral (U.S., Canada, China, Germany, U.K., France) or multilateral (EU Horizon, OECD, IIASA) partners to better explore and identify potential areas of cooperation and joint research.

[Figure 3-3] Status of Carbon Neutrality International Cooperation R&D Projects by Year and Ministry (% , Project Number, 2017-2021)



※ Created by the authors.

3.2 Status of Jointly Commissioned Research with Foreign Countries/ Institutions in Carbon Neutrality International Cooperation R&D

● **This Focus utilizes information on the joint commission status of the carbon neutrality international cooperation R&D projects to conduct additional analysis on the cooperation partner countries and sectors involved in the joint research.**

- This Focus conducts additional analysis by utilizing information on jointly commissioned research, which eases the process of specifying cooperation partner countries and sectors within the dataset, in order to identify such factors regardless of the nature of the jointly commissioned research.
- In the last five years (2017–2021), programs and sub-projects in which foreign countries have participated in carbon neutrality international cooperation R&D projects in the form of joint commission include a total of 165 projects in 4 programs, amounting to a government research funding amount of KRW 76.7 billion. Some of these include: 1) Program to Develop Foundation for International Cooperation, 2) Research to Promote Land, Infrastructure, and Transport Technologies, 3) International Cooperation in Industrial Technology, and 4) International Joint Research in Energy.

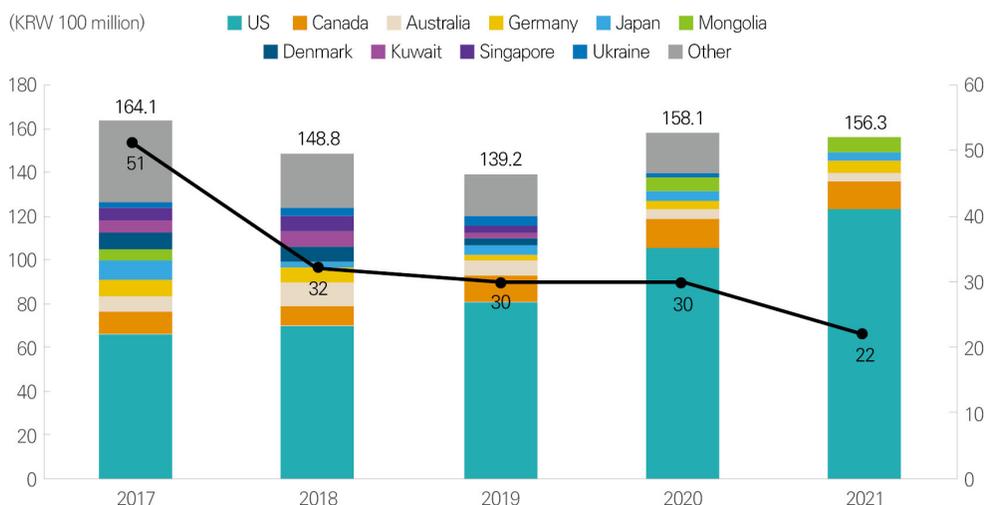
● **Major cooperation partner countries that participated in jointly commissioned research in carbon neutrality international cooperation R&D projects include the U.S., Canada, Australia, Germany, and Japan, among others*.**

* Based on government research funds for programs that participated in joint commission.

- Among the 25 countries that participated in jointly commissioned research in carbon neutrality international cooperation R&D projects, the top 10 countries in terms of government research funding are the U.S., Canada, Australia, Germany, Japan, Mongolia, Denmark, Kuwait, Singapore, and Ukraine, in descending order.
- The primary sectors of R&D cooperation with major partner countries are in the fields of renewable energy, greenhouse gas sequestration, energy storage, and energy demand.
 - As the U.S. is engaged in cooperation across all fields, it can be considered as the most active partner country for R&D exchange in the field of carbon neutrality. Australia, Germany, and Japan are each involved in three fields, while Canada cooperates in two fields*.

* (U.S.) All Sectors, (Canada) Renewable Energy, Multi-Sector, (Australia) Renewable Energy, Energy Storage, Greenhouse Gas Sequestration, (Germany) Renewable Energy, New Energy, Energy Storage, (Japan) Greenhouse Gas Sequestration, Transmission/Distribution/Power IT, Multi-Sector

[Figure 3-1] Main Cooperation Partner Countries in Jointly Commissioned Research of Carbon Neutrality International Cooperation R&D Projects by Year (KRW 100 million, Project Number, 2017-2021)



※ Created by the authors.

● The main sectors of cooperation in jointly commissioned carbon neutrality international cooperation R&D projects are in renewable energy, energy demand, energy storage, and greenhouse gas sequestration*.

* Based on government research funds for programs that participated in joint commission.

- International participation in jointly commissioned R&D projects, in terms of government research funds, follows the order of renewable energy, energy demand, energy storage, greenhouse gas sequestration, multi-sector, new energy, transmission/distribution/power IT, and non-renewable energy.
 - Renewable energy is the sector with the highest number of participating countries, consisting of 15 countries that include major cooperation partner countries, such as the U.S., Canada, and Germany. Energy demand consists of 9 countries, including the U.S., China, and Hong Kong; energy storage consists of 5 countries, including the U.S. and Singapore; and greenhouse gas sequestration consists of 4 countries, including the U.S., Japan, and UK.
 - In addition, various countries are also cooperating in other fields, such as multi-sector (France), new energy (Denmark), and transmission/distribution/power IT (Kuwait and Netherlands).
- In terms of the share of jointly commissioned R&D with international participation relative to international cooperation R&D, the most active fields of cooperation with foreign countries are in greenhouse gas sequestration and renewable energy.
 - The share of R&D that is jointly participated by foreign countries amounts to 88% in greenhouse gas sequestration and to over 65% in renewable energy.

Chapter 4

Implications

4.1 Strategy Development and Investment Expansion for Carbon Neutrality International Cooperation R&D

○ **From a long-term and macro perspective, a comprehensive and clear direction through the establishment of carbon neutrality international cooperation R&D strategy is necessary to achieve carbon neutrality by 2050 and to secure technology sovereignty.**

- There is a need to establish a carbon neutrality international cooperation strategy by setting international cooperation goals by each technological category* that are based on a cross- and in-depth analysis of major partner countries and sectors of cooperation for carbon neutral science and technology R&D.

* Ex) Hydrogen Supply Technology — Securing Cost-Effective Hydrogen Production

- To derive the partner countries and areas of cooperation that can maximize the effectiveness of international cooperation R&D, attempts should be made to monitor the R&D investments and corresponding programs in technologically advanced countries and to conduct a matching analysis between strategic R&D sectors of key partner countries and those of Korea.
 - Currently, there is a mismatch between sectors of R&D projects receiving large investments and sectors with a high share of joint research and collaboration with foreign countries. This calls for a further analysis to determine how and in which sector cooperation with foreign countries and institutions should be carried out.

○ **Expansion in the scale of international cooperation R&D investments is necessary to secure global technological leadership and market dominance in the field of carbon neutrality.**

- Technology alliances with technologically advanced countries and institutions should be built by adopting diverse means to expand support for emerging and promising technologies in the field of carbon neutrality.
 - Investment strategies/plans can be explored to encompass and target: 1) various purposes of support (e.g. international joint research, exchange of human resources, participation in global/multilateral cooperation projects) and 2) stage of research (e.g. securing of innovative technologies, early-stage validation, linkage to commercialization).
- Along with the expansion of investment, it is necessary to systematize the R&D project planning

and identification processes to promote medium- to large-sized flagship projects in the form of full-cycle international joint research by stage of research, as well as mission-oriented R&D projects for the purpose of addressing global climate change issues.

- In particular, from the analysis of international cooperation R&D investment trends in the context of carbon neutrality, findings suggest that the renewable energy sector, universities, and basic research play major roles in international cooperation. Given such, R&D projects with the potential for scale-up can be planned and promoted.
- However, consideration should be given for measures to improve efficiency through the promotion of large-scale, integrated international cooperation R&D that is based on a strategic expenditure review* from examining potential similarities and redundancies between R&D projects at the pan-ministerial level.

* Improves the efficiency of budget allocation by expenditure reduction through streamlining project structures and revision of priorities with consideration for the unique characteristics of each mission.

4.2 Diversification of Cooperation Types and Partner Countries in Carbon Neutrality International Cooperation R&D

- **Defining the strategic partner countries and technologies for cooperation, for the ultimate goal of achieving carbon neutrality, is possible through building multilateral cooperation relations (e.g. formation of a multi-stakeholder platform between technologically advanced and emerging countries from the stage of basic research and increased support for joint research) that can serve as an important foundation for long-term and mutually beneficial cooperation.**
- When establishing multilateral cooperation relations, beyond joint research and exchange between current/ongoing research institutions, participation in consultative bodies of specialized institutions in research management (funding agencies) can expand the exchange between institutions from advanced and emerging nations to develop R&D and policy projects for the purpose of deriving strategic partner countries and technologies for cooperation.
 - For example, Japan participates in the Belmont Forum as a part of its strategic international joint research program to carry out multilateral cooperation. The Belmont Forum is a multilateral organization, comprised of institutes specialized in research management and support, which provides international transdisciplinary research for understanding, mitigating, and adapting to global environmental change. The U.S., UK, Japan, and China are members of this Forum (South Korea is not a member).
- Alternatively, creating a multilateral platform based on technology alliances or exploring methods to engage in such platform through joint calls can lead to the development of programs to build a global value chain for the advancement and commercialization of carbon neutral science and technology with countries in the platform.

- Recently, led by the U.S. National Science Foundation (NSF), the Global Centers Program in the field of climate change and clean energy was developed with the participation and collaboration from Canada, Australia, and the U.K. through joint calls.

🕒 When implementing carbon neutrality international cooperation R&D projects, national hub centers should be leveraged to strengthen overseas data and networks and high-level meeting agendas should be identified to increase the policy utilization of the derived R&D results and to better discuss the procurement of technology sovereignty.

- The foundation for international cooperation can be built by: 1) utilizing overseas hub organizations* of government departments and GRIs as platforms to collect and share local information for the establishment of the necessary infrastructure for technological cooperation, 2) creating a pool of experts based on networks with central government agencies, local governments, and GRIs related to local carbon neutral technologies, and 3) operating capacity-building programs through the hub centers targeted towards industry-research-university groups and policy/decision makers of the host and neighboring countries.

* Science & Technology Cooperation Center (6 regions, ASEAN/Northern Europe) and Overseas Organizations of GRIs (4 organizations, 7 countries).

- Efforts should be made to solidify the basis for bilateral cooperation related to carbon neutrality through high-level meetings (e.g. Joint Committee Meeting on Scientific and Technological Cooperation, JCM*); to organize and operate a working group led by R&D researchers in the field to support the JCM and pursue carbon neutral international cooperation R&D; and to promote country-specific cooperation agendas (e.g. launch of integrated channels for the exchange of human resources, participation in joint research programs) based on mutual consultation.

* Government-led bilateral JCMs have the advantages of strong top-down execution and resource input for R&D.

- Policy utilization of the R&D results is essential to identify the main agendas of JCMs based on the achievements of promoting carbon neutrality international cooperation R&D projects.
- In particular, in the process of concluding a bilateral agreement on greenhouse gas reduction, matters related to Korea's carbon neutral technological cooperation can be actively included. Furthermore, participation of relevant ministries and experts in technological cooperation should be boosted even in bilateral meetings during the implementation of the agreement.

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