KISTEP R&D AND BEYOND 2022

National Strategic Technology | 2030 National Greenhouse Gas Reduction | Mission-Oriented Innovation Policy | Private-Led Innovative Growth


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KISTEP Korea Institute of S&T Evaluation and Planning

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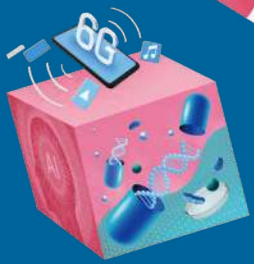

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Editor's Message

At a time when the competition for technological supremacy between the US and China is intensifying, the importance of Korea's science and technology innovation policy and science and technology diplomacy is growing. Fortunately, COVID-19 seems to reach a point where it is shifting from a pandemic to an endemic. However, uncertainty is growing, with the Russia-Ukraine war and Europe's energy crisis delaying the attainment of carbon neutrality.

In this environment, Korea's main policy direction this year is a mission-oriented innovation policy centered on carbon neutrality, national strategic technology, and private-led innovative growth. To support this policy direction, the government is attempting new changes, such as the active use of nuclear power generation and the establishment of the Space Agency in the run-up to the new space era.

In accordance with KISTEP's national strategy and global trends, it aims to secure Korea's technological competitiveness and a reliable supply chain in sectors, including semiconductors, by selecting national strategic technologies amid the global technology competition.
Before embarking on the journey, it is crucial to set the direction of national interests for Korea's economic security. The role of science and technology diplomacy is becoming more critical in expanding the convergence of science and diplomacy, such as bilateralism, artificial intelligence, 6G, and cyber security.

In this KISTEP R&D and Beyond 2022, we have carefully selected articles related to national security technology, 2030 national greenhouse gas reduction, mission-oriented innovation policy, and private-led innovative growth. It also includes "The New Administration's Science and Technology Tasks and their implications", "Risks of the Future Society and Our Strategies for Digital Transformation: Focusing on Artificial Intelligence's negative effects", and "Key Technologies and the Government's Plan to support R&D in the Four Major Areas in response to an infectious disease crisis" as well as R&D infographic, technology trends, Wednesday Forum Focus, and KISTEP news.

KISTEP, as a think tank, presents 15 STI Policy Agendas in 2022: global S&T leadership in the era of Pax America; a healthy, safe, and inclusive society; an innovative economy leading the digital era; innovating a system for the development and utilization of S&T talents in the era of population decline; advancing a system for innovations in the era of KRW 100 trillion national R&D budget. KISTEP researchers continue to contribute to addressing our agendas with research and practice in policy planning, technology foresight, feasibility studies, R&D program evaluation, and science and technology diplomacy.

The publication of KISTEP R&D and Beyond 2022 is a milestone in our journey toward making KISTEP a global think tank.

History

1987 JAN.
Establishment of Center for S&T Policy (CSTP), an affiliated organization of Korea Institute of Science and Technology

1993 MAY.
Reorganized CSTP and renamed it S&T Policy Institute (STEPI)

1999 FEB.
Establishment of KISTEP

2001 JUL.
Reorganized and strengthened planning function of KISTEP

2007 NOV.
Establishment of Korea Institute of Human Resources Development in S&T (KIRD) affiliated with KISTEP

2005 JAN.
Redirected KISTEP's main functions to national S&T planning, coordination and R&D evaluation

2009 FEB.
10th anniversary of KISTEP

2011 MAR.
KISTEP's affiliation was transferred to National Science & Technology Council (NSTC) from the Ministry of Education, Science and Technology

2013 MAR.
KISTEP's affiliation was transferred to the Ministry of Science and ICT from NSTC

2019 FEB.
20th anniversary of KISTEP

2020 JAN.
Relocation to Chungbuk Innovation City

2021 OCT.
KISTEP signed an MOU with KISTEP-KIRD-CIAST-Dankook Univ. to strengthen industry-academia-research institute's cooperation

2022 OCT.
The establishment of Office of Future Technology Strategy

Vision and Strategy

Vision

A global institute that contributes to economic growth and public welfare through strategic S&T planning and R&D evaluation

Mission

Improving the effectiveness of R&D investment through expertise in S&T policy planning and R&D evaluation + Contributing to the development of innovative growth engines by identifying future agendas and strategies

Strategy

- Identifying Future Agendas and Strategies for Enhancing National STI Capacity
- Advancing and Designing the Foundation of National R&D systems
- Creating Innovation Ecosystems by Fostering Innovative Growth Engines

4 Core Functions of KISTEP

- National S&T Policy Planning and Future Strategies
- Budget Allocation and Coordination of Government R&D Programs
- Survey, Analysis, Evaluation and Performance Distribution of Government R&D Programs
- Preliminary Feasibility Studies of Government R&D Programs

Key Achievements

2022 Launched the IRIS (Integrated Research Information System)

2021 Established 'S&T Diplomacy Forum' and 'S&T Diplomacy Academy'

2020 Established 'The 4th Government R&D Performance Evaluation Basic Plan'

2019 Established 'The 2nd Mid- to Long-term Government R&D Investment Strategy'

2018 Established 'The 4th Science and Technology Basic Plan'

2017 Suggested 20 Policy Projects for STI of New Government

2016 Ranked 'Excellent' in Mission-oriented GRI Evaluation

2015 Announced KISTEP 10 S&T Policy Issues of 2015

2014 'The Road to Creative Economy' Forum in Celebration of KISTEP's 15th Anniversary

2013 Established 'The 3rd Science and Technology Basic Plan'

2012 Conducted 'The 4th National Technology Foresight'

2011 Established 'The 2nd Mid- to Long-term Government R&D Investment Strategy'

2010 Established 'The 2nd Mid-to Long-term Government R&D Investment Strategy'

2009 Developed 'The Roadmap for the Green Technology and the Industrial Development Strategy'

2008 Established 'The 2nd Science and Technology Basic Plan' (577 Initiative)

2007 Created 'The Total Roadmap' for Government R&D Programs

2006 Built 'Certification System for Excellence' in Budget Management

2005 Formulated the 'National Evaluation System' and conducted 'The 3rd National S&T Foresight'

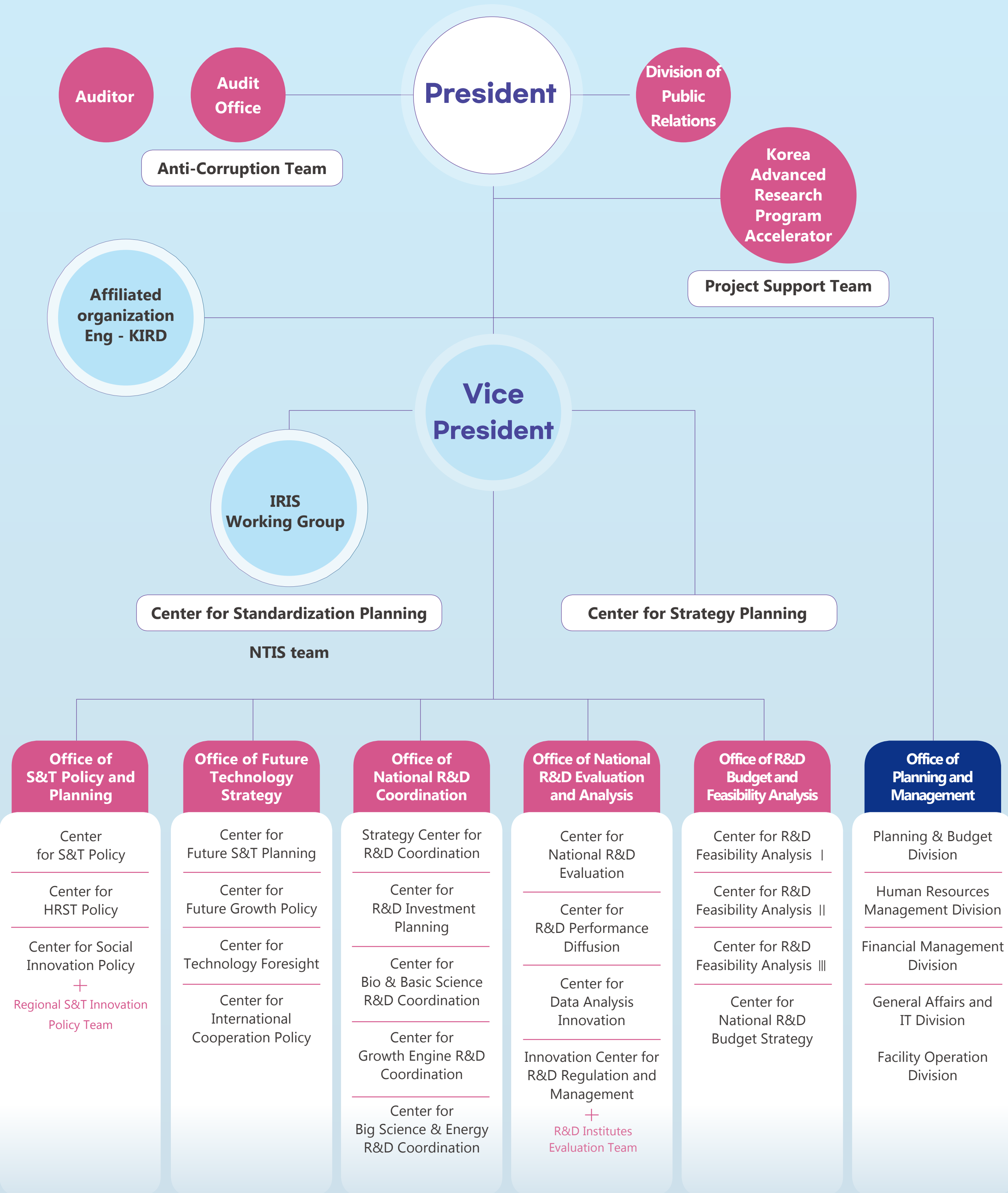
2004 Conducted 'Technology Assessment' on the Convergence of NBIT

2003 Conducted 'Technology Level Evaluation' on 99 Core Technologies

2002 Built the 'Korea R&D Integrated Management System'

2001 Established a Comprehensive Coordination System for Government R&D Programs

Organization



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R&D Keypoint

Summary and implications of the New Government's National S&T Policy Tasks

Meaning of Selecting the National Strategic Technologies and Future Policy Direction

Summary and implications of the New Government's National S&T Policy Tasks

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1. Background

Being inaugurated on May 10, 2022, the Yoon Suk-yeol administration has announced the national vision and goals and 110 national policy tasks for the next five years, aiming to advance the Republic of Korea amid an uncertain international political landscape. The new administration has set "The Republic of Korea makes significant progress as a country where everyone lives well together" as a national vision, embracing the contemporary demand and public needs. And it also set "national interest, pragmatism, fairness, and common sense" as the principles of national governance. Based on that, it proposes six national goals and pledges to the public, 110 national policy tasks, and 521 actionable tasks.

Figure 1 The New Administration's vision and goals

Government Vision

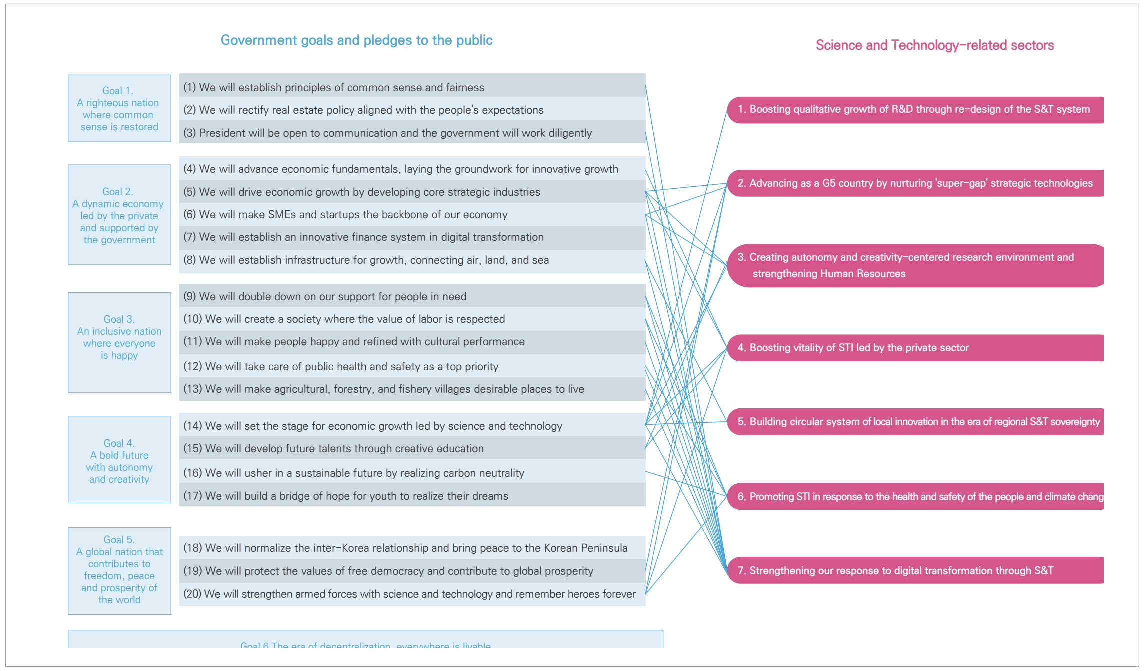
Republic of Korea makes a significant progress as a country where everyone lives well together

Principles of National Governance: Natioal Interest, Pragmatism, Fairness and Common Sense

- **Government Goal 1** → **Politics and Administration** A righteous nation where common sense is restored
- **Government Goal 2** → **Economy** A dynamic economy, led by the private and supported by the government
- **Government Goal 3** → **Society** A warm-hearted nation where everyone is happy
- **Government Goal 4** → **Future** A bold future, brought by autonomy and creativity
- **Government Goal 5** → **Diplomacy·Security** A global nation that contributes to freedom, peace and prosperity of the world
- **Government Goal 6** → **Era of Decentralization** The era of decentralization, everywhere is livable

The S&T sector was mentioned across national policy tasks, centering around national policy goal no. 6, "A bold future created with autonomy and creativity". To respond to various environmental changes such as a steady decline in potential growth rate, slow growth of decent jobs, polarization between regions, classes, and incomes, and deteriorating sustainable welfare and virtuous growth cycle, among other things. This article has put 41 national policy tasks and 136 actionable tasks into seven categories related to S&T based on R&D policies to achieve national policy tasks, actionable tasks, and critical tasks. The summary of the leading implementation direction and contents are as follows.

Figure 2 National Goals and S&T-related National Tasks



2. Main contents of S&T-related national policy tasks

1) Boosting qualitative and quantitative growth of R&D through the redesign of S&T system

A rapidly changing environment such as digitalization, competition of technological hegemony, deteriorating climate crisis, and expansion of natural and social disasters demand the need for an S&T-centered nation and the establishment of a national operation system in which the government and the private sector participate together.

The innovation based on S&T proposes a transition in S&T policy to make Korea an economic power, a security power, and a happy country. To this end, it suggests building a mission-oriented S&T system to tackle national challenges, transition to private-led and local-led policies, strengthen industry-academic-research institute cooperation, and develop and acquire S&T talents. Furthermore, it details strategies and projects reflecting the new government's national policy tasks through S&T Basic Plan, the highest plan in the S&T sector. It also structures governance for implementing policies, such as establishing the Public and Private S&T Innovation Committee to strengthen civil participation, cooperation, and coordination between ministries.

With a steady increase in S&T investment, we are at a threshold of KRW 1 trillion in R&D investment. As of 2020, R&D expenditure as a percentage of GDP stood at 4.81%, ranking the 2nd, a level relatively higher than significant economies in the world. While direct R&D outputs, including thesis and patents, have increased with a concentrated investment in R&d in a short period, the quality of the results still needs to be improved.

The national policy tasks set out the plan to keep the R&D budget at a 5% level of the government's total expenditure and create a system to establish mid-term and long-term investment strategies, and allocate and adjust the R&D budget comprehensively and strategically to enhance the R&D strategy focusing on qualitative growth. Furthermore, it also aims to implement a timely and flexible standby feasibility system that can respond to technological and climate change, improve the evaluation system for the creation of high usability outcomes, and build a plan to facilitate the application of results.

To strengthen mission-oriented R&D and induce the transition to target and marketable outcome-oriented R&D, it shall adopt a mission-oriented R&D system. To address national challenges, it shall pursue mission-centered R&D throughout its lifecycle, from establishing an R&D roadmap for each mission to doubling down on strategy investment to managing and evaluating mission-oriented special programs. To attain this goal, it must first integrate a system for implementation across ministries, pursue program restructuring, and introduce a drastic execution method and flexible R&D system. At the same time, it must implement mission-oriented industrial technology projects on a large scale.

Second, inducing the R&D activities to generate marketable outputs requires expansion of public-private joint investment to facilitate technological commercialization, support of program R&D based on market-user-ministry collaboration, a connection of information networks between technology and commercialization, and strengthening of a sophisticated technology evaluation and quality control method.

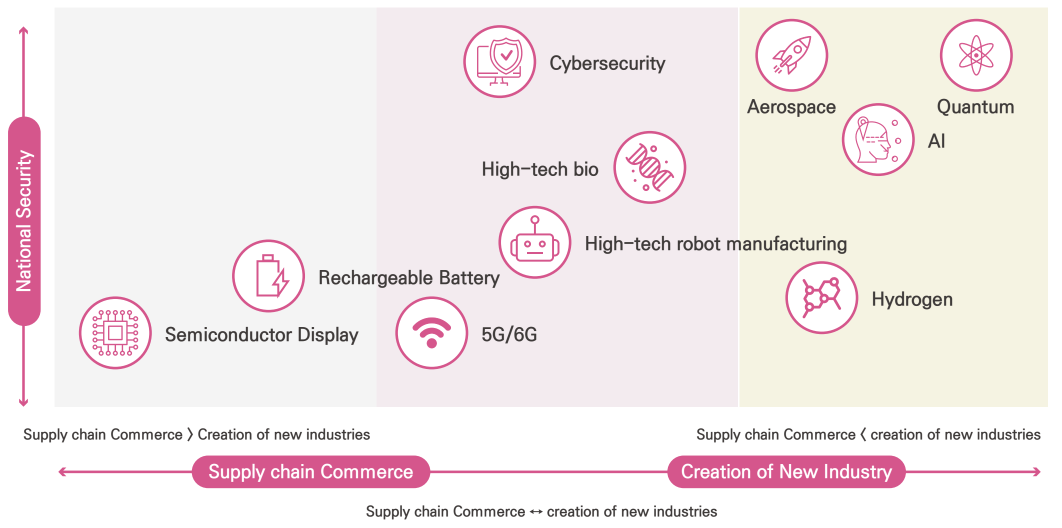
2) Leap forward to G5 through nurturing 'super gap' strategic technologies

One of the key national policy tasks is to expand investment in super-gap strategic technology to prep for technological hegemony. The competition for technological hegemony between the US and China had been triggered by China's neck-breaking economic and technological growth and is likely to continue for the long term. The escalating conflict between them and the spread of protectionism flare up the competition to gain the upper hand in the supply chain, trade, industry, diplomacy, and security fronts by acquiring strategic technologies by country.

Against this backdrop, Korea has designated strategic technologies essential to gaining the upper hand in terms of economic growth and security. It will invest heavily to lead the strategic technologies by a large margin and secure indispensable and irreplaceable technologies. Furthermore, it will build a system conducive to the discovery and development of strategic technologies in order to create a strategy roadmap for each technology, expand the government's investment in R&D, and discover strategic technologies by establishing and operating a Public-Private joint meeting board.

The best experts in each field must lead the planning and implementation of R&D projects based on clearly-defined missions for each strategic technology to develop 'super-gap' technologies. At the same time, the experts in the private sector must play a central role in building a system dedicated to planning and managing R&D projects, such as identifying tasks, portfolio-style study, planning, organizing professional support, and establishing an evaluation and inspection system. Also, government-funded research institutes and universities must be designated core research hubs and activate collaborative and convergent research between the industry, academic, and research institutes.

Figure 3 National Goals and S&T-related National Tasks



Source: Strategy for the selection, development and protection of National Essential Strategic Technologies (draft) (The Ministrial Conference on Science and Technology, Dec. 2021)

It will strengthen cooperation with other countries, centering around strategic technologies. It will solidify strategic partnerships on strategic technologies by presenting cooperative strategies and establishing collaborative platforms with leading countries in each field in accordance with the strategic technology roadmap, expanding the ministerial-level science and technology joint committee to a joint public-private meeting, or joining the "horizon Europe" as a member country. It will aim to improve the visa issuance system to attract talented researchers from abroad and induce an influx of excellent talents. It will strive to elevate international cooperation and its global status by jointly using extensive network of facilities worldwide, such as accelerators (synchrotron radiation, rare isotope accelerator), space particle research facilities, ultra-intense laser research facilities, and supercomputers.

3) Creation of autonomy & creativity-centered research environment and strengthening of talent development

Maintaining and boosting the competitiveness of national science and technology necessitates the creation of a research environment under which research capabilities can be retained and accumulated. It also requires S&T human resources to inflow continuously and be utilized. The National policy tasks suggest establishing a conducive research environment that does not interfere and supports autonomy- and creativity-centered basic research. Along with researcher-led basic research, investment in strategic basic research, reflective of national demands for high-tech science and technology, was expanded while improving the evaluation process and conducting an audit focusing on the research process laid the foundation for innovative and challenging research. In addition, it will strengthen the efforts to support basic research throughout the research lifecycle with measures such as launching a new program to develop promising young scientists and establishing a system of honor and benefit for the best scientists.

Second, it will expand systematic support and develop S&T talents. To foster vital human resources in strategic technology fields, it will develop universities as critical centers for basic research and talent development. And it will build a system for fostering and acquiring core S&T talents in super-gap technology fields under the master plan for promoting talents in super-gap areas through pan-ministry, Public-Private cooperation in five major mega-tech areas. Regarding digital resources, the goal is to develop one million talents in the digital field by creating a workforce specialized in the digital, metaverse, and semi-conductor fields and building a foundation for systematic training in SW, AI, and digital areas and the environment for edu-tech training. Furthermore, it strives to establish a talent development system throughout lifecycle: for the youth, expanding scholarship system, research opportunities at home and abroad, and revamping military service system for S&T field; for female S&T talents, strengthening customized online and offline service throughout lifecycle; for the middle-aged and seniors, expanding transition training and pushing back the retirement age for outstanding researchers.

4) Boosting the vitality of private-centered S&T innovations

Among the new government's national goals is "a dynamic economy, led by the private sector and pushed by the government". Through that, the government presents a fundamental philosophy under which the government devises a system, making the market fair and efficient and the private sector leads economic growth. The government also sets out a national policy task for the S&T sector that is led by the private in acquiring S&T capabilities, activating state-of-the-art technology and deep-tech startups, and ultimately contributing to the national economy.

First, it will boost support for private R&D tax schemes, such as expanding the scope of R&D tax deductions in new growth technologies, source technologies, and national strategic technologies to strengthen the S&T capabilities of the private sector. Most R&D has been funded by the government so far. However, it is to provide customized R&D packages to respective corporate R&D centers for each innovation capability by introducing various R&D support methods, such as equity investment, financing, and rewards. Also, it will build a standing cooperation channel between technological or industrial committees with relevant ministries and expand the participation of the private sector in the process of R&D policy development and budget allocation and adjustment. Second, it will innovate regulations to inject vitality into new industries. It will proactively identify regulatory issues, suggest the direction of regulatory improvements to a relevant ministry, and check for implementing the regulatory improvements in policies. Furthermore, it will utilize Big Data and AI technology to innovate the process of regulatory administration, spur new industries with regulatory sandbox plus (system overhaul), and introduce a negative regulation system into major new sectors. To do that, it will adopt a "conflicts resolving regulatory sandbox" to resolve disputes of interest in new industries, select core sectors, re-design laws governing corresponding industry processes, and operate a pan-government council.

The current special zone has allowed pre-determined operators to be exempted from pre-specified regulations. However, it will establish a "global innovation special zone" for each area by adopting a "regulation-free special zone 2.0" where everything is allowed freely except for things banned by other laws. Third, it will materialize a comprehensive ecosystem for venture companies, from startups to unicorns, to spur innovations in the private sector. It will build the ecosystem for university-based startups tapping into human capital and technologies possessed by a university and activate cutting-edge technology and deep-tech startups centering around new industries. To that end, it will increase startups-centered universities, conduct online and offline training for startups at universities, launch a "1,000 super-gap startup project", and expand the TIPS program. It will also develop packages for startup support and roll out more programs to assist in preparing for private-led startups.

It will increase the fund of funds (FoF) to provide financing support to venture companies and strengthen its pump-priming role for private Venture Capital, such as ease of M&A investment restrictions. It will heavily invest in super-gap funds, scale up funds, and advance to middle-market enterprise funds, youth, female entrepreneurs, and early startups funds. Also, it implements expansion of overseas infrastructure for startups, such as the establishment of the Global Unicorn Project ", a program to support Korean startups to venture into foreign markets, and diverse scale-up programs, such as establishing policy funds and providing technology assurances. To create an accelerating and smooth environment for startups, it aims to discover viable companies in advance, offer customized services to each startup on a second trial, and provide funds specifically for second-time startups.

5) Establishing a virtuous cycle of local innovation in the decentralized S&T era

The national tasks in the S&T sector for local revitalization are as follows. First, it will boost original innovation capabilities for regional recovery and sustainable growth. To that end, it will promote local independent mid- and long-term innovation projects, such as region-led R&D projects to develop original core technology in the promising technology field, expand regional basic research support, and support quality research competitiveness. Furthermore, it selects and operates a mega-regional government-funded research institute, revitalizing the mission-oriented regional organization.

The national tasks in S&T sector for local revitalization is as follows. First, it will boost original innovation capabilities for regional recovery and sustainable growth. To that end, it will promote regional autonomous mid and long-term innovation projects, such as region-led R&D project to develop core original technology in the promising technology field, expand regional basic research support, and support quality research competitiveness. Furthermore, it selects and operates a mega-regional government-funded research institute, revitalizing mission-oriented regional organization. Second, it will promote open convergence research, closely connecting local industry-academia-research institutes. It creates a partnership between local universities and national research institutes, supports joint local innovation activities, and designates a "local technology hub" linked to the national strategic technology. By doing so, it will induce cooperation between industry-academic-research institutes. It aims to promote the creation of new local industries and new growth engines based on local S&T achievements, focusing on special R&D zones and research industry complexes, such as introducing and expanding a new model of small but strong special zones reflecting local demands and conditions.

Finally, it will establish the S&T-focused tailored system to spur growth and development. As each region has different resources and capabilities, it will propose an S&T-centric development path specific to each region, develop a regional strategy, and strengthen the regional S&T think tank. To this end, it will set up a joint decision-making system where the central government and the local government participate together and promote the enactment of 'the Regional Science and Technology Innovation Act' (TBD) for implementing and governing S&T policy and industry stably and comprehensively.It will help identify future growth engines for local SMEs, the primary players in regional innovation through developing leading mega-regional companies, strengthening links between regional innovation centers (TP and creative economy centers), establishing and operating regional crisis support centers, and supporting regional talents' settlement. Also, it will help make five major mega-cities as innovative economic hubs that attract companies and young people, such as corporate innovation parks, urban convergence zones, and campus innovation parks. It will also create global innovation zones for each region.

6) Promotion of Science and Technology Innovation for public health, safety, and climate change

Recently, the environment has been changing so fast that it is dubbed the transformation era. Regional and global disputes over resources are intensifying as the supply and demand of energy, water, and food become unstable. Climate changes like global warming heighten uncertainties, such as extreme weather patterns, natural disasters, and new infectious diseases. Low birth rates and an aging population are weighing on national finances with diminishing growth potential and rising welfare costs. The new government will propose national tasks to response to the evolving environment through technology development. First is innovation in bio and digital health care. It will establish a public-private 'National Bio Innovation Strategy' to set core tasks and a roadmap. It will also select disruptive technologies, such as synthetic biology, microbiome, brain science, aging, stem cell therapy, electroceuticals, digital treatments, and next-generation infectious disease response technology to lead future markets and implement pan-government projects. Furthermore, it will build a system for investment in innovative R&D and spread Big Data-based cutting-edge precision medicine to tackle national challenges, such as upcoming infectious diseases in the post-COVID-19 era.

Second, it will spur technology development to respond to crises and changes. It will establish a digital disaster management system utilizing AI and Big Data as well as scientific and evidence-based national infectious disease governance and quarantine system. To that end, it proposes specific measures, including establishing institutions and systems capable of speedy and flexible responses, a Big Data platform, strengthening monitoring, diagnosis, and prediction capabilities, and making an early warning system and an integrated portal site for disaster prevention. One crisis surrounding Korea is the volatile inter-Korea and international relationships. To address such a crisis, it will establish an innovative, open, and convergent R&D system for the national defense system that industry-academic-research institute-military organically interconnected based on advanced science and technology and reinforce the national response capabilities in cybersecurity. To support that, it will organize the presidential 'Public-Private Council for Defense Innovation 4.0' and 'National Cybersecurity Council' to boost execution capabilities substantially.

The third is the energy and green industry innovation in response to climate change. To realize that, it will secure the next-generation nuclear power technology, such as developing an independent SMR reactor and the 4th generation reactor and convergent nuclear energy, creating a nuclear power ecosystem, and solidifying the ROK-US nuclear alliance. On top of that, it will devise highly feasible measures to fulfill carbon neutrality, stimulate decarbonization of economy and industry, intensively develop five new green industries, such as biogas, circular resources, climate tech, environment IoT, and water components, and make a heavy investment in R&D to resolve environmental challenges facing the nation.

7) Strengthening response capabilities to a digital conversion through science and technology

Innovative ICT technologies, such as AI, Big Data, and 5G, are applied in diverse sectors, creating digital-based new industries and services and promoting a digital conversion of the existing industry. First, it will develop next-generation AI core technologies and AI convergence projects focusing on sectors closely related to people's daily lives, aiming to secure the world's best technologies, such as AI, intelligent semiconductors, metaverse-based technology, 5G and 6G, cybersecurity, and quantum. In addition, it will integrate the existing industries with digital technology, such as manufacturing industry service, logistics, and construction innovation, future ship technology, and smart agriculture technology. Second, it will develop the next-generation core digital technology, such as installing and advancing 5G networks, 6G, and satellites to accelerate the construction of the world's best network and digital innovation. It will also secure the safety of the network and SW, such as constructing an ecosystem for open-RAN equipment early on, ensuring SW safety close to people's lives, and completing digital conversion in the primary safety areas. It will also establish a comprehensive support system to expedite digital innovation across industries and regions, focusing on AI and SW, make five major mega-regional digital innovation hubs, centering around small but strong cities and mega-regional cities, develop human resources in those areas, and implement a large-scale project.

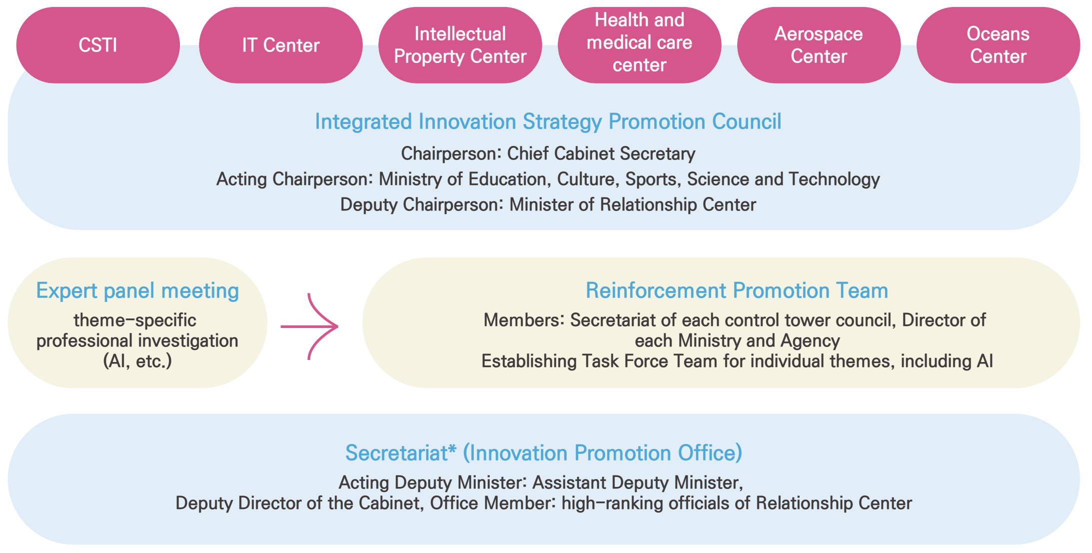
3. Conclusion

As discussed earlier, the new administration emphasizes the role of innovation and S&T in the overall national tasks. It is necessary to manage state affairs and expand STI policies, focusing more on S&T to materialize S&T-centered national innovation in the future. S&T resolves pressing national issues, such as digital transformation, technological hegemony, the spread of disasters, climate change, and decreasing population. S&T also actively contributes to a broad range of economic and social challenges. Furue role of S&T is likely to be more emphasized. Therefore, the scope of S&T policy needs to be expanded from the current R&D-centered to the entire S&T innovation. Indeed, "the 5th Basic Plan for Science and Technology (2023-2027)" under development this year is deriving tasks by expanding major policy areas from the current S&T-centric to economic, industrial, and social innovations across the board. Besides the Basic Plan for Science and Technology, legal and non-statutory plans are being promoted in the S&T field. (84 plans in total as of the end of 2021) To be aligned with the Basic Plan for Science and Technology, mid and long-term plans in the S&T field need to strengthen their connection with the Basic Plan for Science and Technology by expanding their areas from the perspective of innovation policy.

Second, establishing the S&T-centered integrated implementation system is necessary to implement major national tasks and respond swiftly. The new government has proposed the "Public-Private S&T innovation Council" as S&T governance. If the "Public-Private S&T innovation Council" acts as a deliberation body, its impact will decrease even if the S&T policy expands into innovation policy. Therefore, the policy coordination role of the "Public-Private Science and Technology Innovation Council" must be reinforced. Also, the government must build a system to link and cooperate with other S&T-related Public-Private Councils like the Digital Innovation Council.

In the case of Japan, it has established and is operating the "Integrated Innovation Strategy Promotion Meeting" in the Cabinet to promote substantial cross-sectional coordination between control tower meetings closely related to innovations and implement the "Integrated Innovation Strategy" (promoting action programs each year to materialize the Basic Plan for Science and Technology Innovation and a long-term vision, including general innovation policies). The Chief Cabinet Secretary is the chairman of the Integrated Innovation Strategy Promotion Meeting. Still, the Council for Science and Technology Innovation (CSTI), the highest organization in S&T policy, is leading the meeting. As seen in the case of Japan, each ministry must be responsible for implementing innovation-related policies, and a diverse Public-Private committee must spring up to coordinate these policies. The role of the Public-Private Science and Technology Innovation Council must be strengthened to structure a system for the governance of Science and Technology Innovation policies.

Figure 4 Implementation system of the Integrated Innovation Strategy Promotion Meeting in Japan



Source: Japan's integrated innovation strategy and its implications (S&T GPS issue analysis Issue 116, Sep. 2018)

Furthermore, it is necessary to solidify relations and collaborations between Ministries and increase the Private sector's participation to ensure the smooth implementation of national tasks and comprehensive innovation policies. As discussed above, there are clear common goals like mission-oriented R&D, but many tasks need cooperation between ministries. Accordingly, it is necessary to break down barriers between Ministries by dividing roles for each Ministry and drafting a roadmap to attain common goals and strengthen links, cooperation, and operation between Ministries.

The role of the private sector also needs to be reinforced. Private experts with different perspectives and backgrounds must be sought after on the industry and strategic technology levels to get them to participate in developing and implementing innovation policies. Also, it must create a structure that enables industries to voice requirements actively. Their voices are proactively reflected as much as possible through an active industry-level consultative body that operates in practice, not in name only.
Last but not least, it is necessary to digitalize S&T-related information and strengthen its use for evidence-based efficient decision-making.

Korea has made great efforts to create and utilize S&T-related information. However, policy needs are changing rapidly, and evidence data is necessary for the problem diagnosis, but there are limitations in creating new data. Consequently, it needs a structured approach to discovering and generating information on science and technology innovations, such as technology, human resources, and industry. It also needs to digitalize the science and technology field, such as data platformization and AI-based analysis prediction. The new government is stressing digitalization in public administration, like a digital government. Building an information system necessary for rational decision-making is critical as more stakeholders are related to policies and get complicated. Consequently, extraction and utilization of S&T-related information are all the more crucial.

Meaning of Selecting the National Strategic Technologies and Future Policy Direction

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1. Introduction

The fierce US-China competition over hegemony and the global supply chain crisis indicate that the political, economic, and industrial landscape is changing, signaling a full-blown reshuffling of the global order. Major countries like the US, China, Japan, and the EU are prioritizing their respective national interests and competing against each other to get the upper hand in the struggle for technological supremacy by detailing their national strategies and putting them into action. Looking deeper into the heated competition backed by checks and balances between countries and alliances, there are strenuous efforts to preoccupy cutting-edge and strategic technologies ahead of others. Technologies are at the center of the latest critical strategies announced by the US, China, the EU, and other countries. Possession of S&T capabilities is not just a matter of livelihood. It is a critical matter that can determine the future of a nation. Therefore, the strategic moves are very fast in speed, and strategies are very aggressive in content. The US has enacted 'the Chips & Science Acts' to intensively support semiconductor industry and 10 core technologies[1] under bipartisan cooperation. It also expressed a strong commitment to implementing a self-sufficiency plan in the rechargeable battery, EVs, and bio industries. China has declared a strategy to make core proprietary technologies self-sufficient by selecting seven S&T and eight industries[2] and heavily developing them. Japan has enacted 'the Economy Security Act' since the inauguration of the Kishida Cabinet and added an economic security office within the Cabinet Office, commencing the research and analysis of 20 critical technologies[3]. The EU has announced a plan to grow six new industries[4] and accelerates to secure core technologies to overcome the energy crisis in the wake of the War in Ukraine.

Table 1 The development of strategic technologies in major countries and a strategy for the stronger governance

USA	• Enacting'the Semiconductor and Science Act' that supports Semiconductor and 10 core technologies heavily under bipartisan cooperation - USD 5.27 million in Semiconductor in the next five years, and investing USD 20 million in developing core technologies like AI and Quantum • Establishing an organization for technology innovation and research security within NSF and establishing the White House-led Science and Technology Strategy (every four years) • Promoting independence of manufacturing and raw materials through IRA (EVs and battery) and Life Science initiative
China	• Intensive development of 7 science technologies and 8 industries, aiming to become independent in core proprietary technologies • Securing the domestic supply chain and promoting 'the Digital Silkroad', targeting developing countries
Japan	• Enacting the Economic Security Act in May 2022, since the inauguration of the Kishida cabinet, and establishing the Economic Security Office • Designating 20 specific critical technologies by installing the Economic Security Research Institute and supporting research
EU	• Accelerating the attainment of core technologies to overcome the energy and climate crisis triggered by the War in Ukraine • Fostering 6 new industries and strengthening the supply chain cooperation with the US through the Technology and Trade Council

Korea must not be an exception. Most of Korea's industries depend on technologies and find themselves at a crossroads of the restructuring order of the global industries. It is high time to concentrate our resources in specific sectors for the sake of our future, develop a comprehensive strategy to grow and safeguard technologies, and put it into action without disruption.

[1] ①AI/Machine Learning/Autonomy, ②High-performance computing/Semiconductor/High-tech computer HW·SW, ③Quantum information science technology, ④Robotics/Automation/Advanced Manufacturing, ⑤ Prevention and Mitigation of natural or man-made disaster ⑥Advanced communications/Immersive Technology, ⑦Life science/Medical technology/Genetics/Synthetic biology, ⑧Data storage·management/Cybersecurity, ⑨Advanced energy(battery, advanced nuclear power generation), ⑩Advanced material science(composites, 2D materials)

[2] Seven major S&T: AI, Quantum, data IC, brain science, genetic bio, clinical medicine, health care, aerospace, deep sea, polar region exploration, eight major industries: advanced new materials, major technology equipment, intelligent manufacturing and robotics, aviation engines, BeiDou Navigation Satellite System, new energy automobile, new medical devices, new drugs, agricultural machinery

[3] Hypersonic, transportation, AI/machine learning, advanced computing, semiconductor, quantum, medical and public health, brain-computer interface, aerospace, marine, advanced energy, chemical, biological, and radioactive materials and nuclear, advanced monitoring, measurement, sensor, data science, cybersecurity, advanced information communication, bio, robotics, advanced materials, and advanced engineering and manufacturing

[4] Raw material, battery, ram materials for pharmaceuticals, hydrogen, semiconductor, cloud and edge technology

In that regard, the Office of Science, Technology and Innovation Coordination, Ministry of Science and ICT has completed the journey to select 'the National Strategic Technologies' in consultation with other ministries and the private sector. That signals the new Korean government's commitment to responding to upcoming changes, such as the competition for technological supremacy, energy crisis, and climate crisis, and to 'the new growth engine' and 'S&T superpower' by developing and proposing a concrete response.

This article will first introduce the selection process of the National Strategic Technologies. It will contain criteria for each step of the selection process and some concerns. In addition, various support policies drafted to protect, nurture, and obtain future national strategic technologies will also be covered.

2. The Selection Process of the National Strategic Technologies

1) The section of 12 national strategic technologies

As a follow-up measure to the ROK-US summit that has established a partnership in the advanced technology sector, ministries have worked together to select "10 National Strategic Technologies" to deal with competition over technological supremacy. Since then, through the ROK-US summit this year, "nuclear power" has been added as a new area of cooperation. Also, it is projected that cooperation in the advanced technology sector will be discussed in the economic cooperation system like IPEF. As such, the external environment is changing.

Furthermore, global politics became recently unstabled in the aftermath of the Russia-Ukraine war, consequently heightening the global energy security issue. In response, Korea is setting up national projects to commercialize "mobility" and "next-generation nuclear power generation" as our future strategic industries. Likewise, the domestic policy landscape is also changing with Korean companies' announcement of active investment plans.

Against this backdrop, there emerges a need to revisit the current national strategic technologies to keep pace with the evolving external environment, leading to the demand survey of ministries on the existing strategic technologies[5] that may need to be integrated or adjusted. After that, the AHP evaluation was carried out for 105 experts[6] regarding strategic technology candidates. The evaluation comprises three major categories: Supply chain and trade, Diplomacy and security, and new industry. Each category was assessed based on detailed evaluation topics, such as external competitiveness, irreplaceability, the potential of a new industry, the influence of innovation, applicability in the national defense, and difficulty of technology adoption.

Table 2 Evaluation Categories for the selection of national strategic technologies

Supply Chain Trade	• (External Competitiveness) Important to keep competitiveness due to a larger economic share and high leverage effect in global trade system • (Irreplaceability) Any potential disruption in the supply chain and the international cooperation can threaten Korea that has a high external dependency
Preoccupying new industry	• (New Industry Potential) High growth potential, the national competitiveness and market dominance will be determined by preoccupation of technology and standards • (Innovation Influence) Due to a big ripple effect on the existing industry and applicability to other sectors, it contributes to the future paradigm shift
Diplomacy and Security	• (Defense Applicability) Highly applicable to the national defense field, Will strengthen combat force drastically if applied in the future battlefields • (Difficulty of technology adoption) Challenging to trade and adopt due to international treaty, control system and alliance blocks

Firstly, from the perspective of supply chain and trade, strategic technology is a technology that requires threat management as its significance in our economy is high at present. A technology with external competitiveness, as a detailed evaluation topic in the supply chain and trade category, refers to a technology that is important in our economy and industry, is capable of achieving a sustainable technology transformation and competitiveness, and has a leverage effect in the global trade system. An irreplaceable technology is a technology that can be exposed to a national difficulty in a potential disruption in the supply chain and international cooperation, considering the external dependency of significant technologies in the global value chain.

Secondly, strategic technology, from the perspective of the dominance of a new industry, is a technology that may have a critical impact in the future and change the economic and social paradigm. Specifically, a technology with a new industry potential refers to a technology with high growth potential as a technology or in the industry where the technology is being applied and can determine national competitiveness and market dominance by dominating the technology or relevant international standards.

[5] A demand survey was conducted for major R&D ministries, such as the Ministry of Science and Technology (1, 2 Vice Minister), the Ministry of Land, Infrastructure and Transport, the Ministry of Oceans and Fisheries, the Ministry of Health and Welfare, and the Korea Intellectual Property Office between June 16 and June 28 2022

[6] Face-to-face evaluation of 105 experts, including the technical committee of the National Science and Technology Council, PD of the Ministry of Trade, Industry and Energy, and diplomatic and security experts

A technology with an innovation potential is a technology that can have a ripple effect in the conventional industry and contribute to the future paradigm shift if the technology is advanced and commercialized.

Lastly, strategic technology, from the standpoint of diplomacy and security, is a technology that is highly applicable to the defense sector and requires self-sufficiency due to export control between countries. Specifically, a technology with applicability in the national defense means a 'game-changer' that can be utilized in the weaponry system and can strengthen a combat capability drastically in future battlefields upon its application. The difficulty of technology adoption indicates how challenging a technology is to trade or adopt due to an international treaty, a control mechanism, and an alliance bloc despite its significance in the public sense, such as diplomacy and security.

Before evaluating strategic technology candidates, the reference package was put together and distributed to the evaluators. Based on the information package, each evaluator has made an evaluation independently and objectively. Later, based on the results of the AHP quantitative evaluation, the strategic values of technology and the urgency of policy support for the technology were discussed and reviewed. Experts in the budget allocation and budget adjustment of the national R&D program and R&D policies, diplomacy and security, and technology experts have participated in the discussion and review. Finally, 12 strategic technologies have been selected at the plenary session of the National Science and Technology Council after the review of the Strategic Technology Planning Board and inter-ministerial discussions.

The process to derive strategic technology

Demand survey of Ministries	Experts' quantitative evaluation	Focus review by experts	Technology Selection
Integration & adjustment and additional suggestion	AHP evaluation per evaluation criteria	Evaluation results of additional technologies and review for integration & adjustment	After the discussion between relevant Ministries, deliberation at the National Science and Technology Council meeting
Relevant Ministries	105 Experts	Technology/Diplomacy/ Security Experts	Public-Private Cooperation

Finalizing the 12 national strategic technologies

①Semiconductor·Display, ②Rechargeable battery, ③Advanced mobility, ④Next-generation nuclear power, ⑤Advanced bio, ⑥Aerospace and ocean, ⑦Hydrogen, ⑧Cyberseucurity, ⑨Artificial intelligence, ⑩Next-generation communications, ⑪Advanced robotics·Manufacturing, ⑫Quantum

Among the technologies included in a survey were advanced mobility, next-generation nuclear power, and polar regions and ocean. These are topics mainly discussed in the quantitative evaluation and an in-depth review. The main discussions are as follows.
First, 'advanced mobility is one of the national future strategic industries that is the future direction of our mainstay industry and has a high potential to create a new industry. Therefore, there was a view that it was critical to gain the upper hand in this sector. The private sector alone can do only so much in developing, demonstrating and verifying proprietary technologies as well as deregulation. Therefore, the government needs to provide policy support for a national strategic technology, as some opine.

Next was the next-generation nuclear power. In the experts' focus review, it was viewed as a core technology that can help fulfill carbon neutrality and energy security. Also, it was deemed as an area that would allow Korea to exercise a diplomatic leverage in dealing with major countries. Cooperation in the next-generation nuclear power can be utilized as a substantial diplomatic opportunity. Therefore, there was a view that Korea needed to take a strategic response by designating the next-generation nuclear power as a national strategic technology to lead future discussions in a multilateral cooperative body.

Lastly, polar regions and oceans are symbolic in the environmental and diplomatic aspects and are public domains that demand state-led technology development. However, there were views that they were relatively less urgent than other strategic technologies in terms of technology leaks, disputes, and standards domination. Likewise, there were mixed views, but ultimately if they meet aerospace, they can generate a synergy effect.

2) Deriving 50 core technologies

After selecting the national strategic technologies, a working group was organized to derive core technologies in each sector. Considering strategic values from economic, diplomatic, and security perspectives, their ripple effects, and the global landscape for competition over them, core technologies that need focused sectoral support have been reviewed. A draft of working-level discussion results between relevant ministries and core sub-technologies in major countries has been referenced.

It looked into core technologies from strategic value, technology level, and lifecycle aspects. First, the strategic value indicates the significance of strategy in the national economy and the supply chain, the innovation of a new industry, and the national security terms. It also refers to a technology that needs mission-oriented goal setting and a roadmap proposal. To that end, it considered strategic technologies and major countries, such as the US, China, the EU, and Japan, and domestic policy priority. As for the technology level, it used major countries' strategic technology systems for reference. It also considered whether a technology would be attainable with a certain level of R&D investment. From a lifecycle standpoint, besides mature technologies, basic and proprietary technologies have been comprehensively considered to select core technologies. Summary of 12 National Strategic Technologies and 50 core technologies

Table 3 Principles of deriving core technologies

Global industrial competitiveness & High significance in the supply chain	New growth's ripple effect & Diplomatic and security values	Development of Mission-oriented technology & possibility of performance creation in 5-10 years

1. Semiconductor and Display

A semiconductor is a device that processes (computation, control, and conversion) input information (data) from an external source, taking up more than 20%[7] of Korea's exports and serving as a pillar of the Korean economy in the past 40 years. The semiconductor is the technology that has triggered US-China competition over technology hegemony. It can threaten economic security if the competition to secure the supply chain gets fierce and leads to losing competitiveness and strategic control. Korea possesses the world's best memory semiconductor technology and excellent foundry and process technology. Korea is striving to lead the future system semiconductor, like AI, based on memory technology. As the demand for AI semiconductors is expected to increase due to the recent strengthening of AI utilization, semiconductors that execute large-scale operations with high performance and high power efficiency are required. In the case of memory, high-integrity and resistance-based memory, which has large capacity and bandwidth compared to the previous one, and operates at high speed at low power, is drawing attention as a next-generation technology. In particular, chemical-based power semiconductors such as GaN are emerging in terms of power efficiency to overcome the limitations of existing silicon semiconductors. In addition, advanced packaging technology to overcome the limitations of miniaturization of semiconductor processes is also considered important, and high-performance sensing technology essential for next-generation electronic systems is continuously attracting attention.

Next, displays are collectively referred to as devices that visualize and display information, and Korea occupies about 37% of the global market[8].

[7] Source, the Korea Semiconductor Industry Association, National IT Promotion Agency

As a major industrial field, it can be seen as a critical field responsible for economic security and base technology for the 4th industrial revolution, such as VR/AR and Metaverse. In the OLED field that Korea focuses on after LCD, fierce competition is underway between countries (China and Japan) for next-generation technology supremacy. Currently, Korea maintains its No. 1 position in the OLED market based on its technological superiority, but the market share gap has been decreasing since 2018 as China has expanded OLED production[9].

It is necessary to maintain global competitiveness by securing the technological advantage of inorganic light-emitting displays based on the competitiveness of existing OLED technologies. Similarly, the freeform display must preoccupy new markets based on technologies currently applied to foldable phones and rollable TVs. In addition, it is urgent to secure technology for basic materials, components, and equipment when the localization rate of basic materials, components, and equipment is about 60-70%.

Short-term(-5years)	Mid and long-term(5-10years)
• Ultra-high performance memory, power efficiency of AI and power semiconductor • Development of NG DP proprietary technology including Micro LED	• Stronger market competitiveness with early commercialization of power semicondutor and sensor • Self-sufficient core supply chain of semiconductor packaging and DP materials, components, and equipment

- High density, resistance-based memory
- Semiconductor Advanced Packaging
- Inorganic Light Emitting Display
- Low-power, high performance AI semiconductor
- ext-generation, high-performance Sensor
- Semiconductor, Display Materials, Components, and Equipment
- Power Semiconductor
- Freeform Display

2. Rechargeable battery

A rechargeable battery is a battery that is repeatedly charged and discharged several times and is used as a critical component in various fields, such as IT, electric vehicles, defense, etc. It has a higher energy density than lead-acid batteries, making it highly usable. Thus, efforts are being made to increase the capacity and stability of the current batteries through structural innovation. Korea has secured competitiveness in manufacturing rechargeable batteries and accounts for 34.7% of the global electric vehicle battery marketas of 2020[10]. Meanwhile, a race to develop next-generation rechargeable batteries with higher energy density is heating up due to the limitation of 330-350Wh/Kg.

[8] Source, the Korea Display Industry Association
[9] Source, the Korea Display Industry Association
[10] OMDIA Source, OMDIA

As Korea is less competitive in the material field than the rechargeable battery manufacturing field, it is necessary to develop core materials to overcome its technical limitations. In addition, it is required to preoccupy the global market through the early commercialization of next-generation secondary batteries that can dramatically increase performance and stability. The battery market is expected to develop mainly centering around mobility in the future, and for this, it is necessary to develop technologies to secure the performance required by mobility. As spent batteries are expected to increase rapidly, related markets are expected to grow. Therefore, Korea must prep for technologies to reuse spent batteries and retrieve valuable metals.

Short-term(-5years)

- Keeping market leadership with technology development by strengthening high capacity and safety of 4 core materials (cathod·anode·electrolyte·separator)

→

Mid and long-term(5-10 years)

- Early commercialization of Solid-state battery and Lithium sulfur battery
- Respond to new markets, like reuse of used battery and raw material recycling technology

- Lithium Ion battery and core materials
- Module and system for Secondary battery
- Materials and cell of neext-generation secondary battery
- Reuse and recycle of secondary battery

3. Advanced Mobility

Advanced mobility is a safe, convenient, and eco-friendly mobile technology based on all transportation means and infrastructure from the users' point of view. In mobility, Korea has some technologies (e.g., eco-friendly cars). Still, it needs to catch up with advanced technologies and localize components (e.g., hydrogen car parts). The automobile industry is expected to shift from the existing manufacturing-oriented to software-oriented convergence and service industries. Related industries are also expected to revitalize by discovering new services and business models using self-driving vehicles. As for UAM, advanced countries, such as the US and the EU are currently leading the creation of a new future aviation market beyond the conventional aviation industry. In response, Korea is strengthening its business strategy to preoccupy a new industry through a consortium of Korean companies.

In the case of AV, considering the timing of commercialization envisioned by the government and the private sector, it is necessary to secure level 4+ technologies, and it is urgent to secure electric and hydrogen vehicle technologies to prep for stricter global carbon-neutral and eco-friendly policies. As UAM has high growth potential in conjunction with various field, such as transportation, communication, and defense, it needs strategic support to secure infrastructure technologies and prepare institutions and certifications.

Short-term(-5years)

- World-best technology development including commercialization of Lev. 4 AVs
- Development and demonstration of core technologies for UAM commercialization

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Mid and long-term(5-19 yrss)

- Advancement of AVs and technology development of communication and certification infrastructure for overall urban traffic system on land and in the air

- Autonomous Driving System
- Hydrogen Vehicles·Electric Vehicles
- Urban Air Mobility (UAM)

4. Next-generation Nuclear Power

Next-generation nuclear power is a future nuclear power system, such as SMR technology, with enhanced stability, economic efficiency, and multi-purpose utilization compared to large nuclear power plants. It is emerging as an alternative to existing large-scale commercial nuclear power plants. In addition to power supply, it can be used in various ways, such as as a propulsion energy source for space in the future and ships. In addition, it is highly promising as a future energy source as its heat and power can be used for multiple purposes, such as power supply in remote areas and islands, heat supply for industrial processes, hydrogen production, and seawater desalination. The Yoon Suk-yeol administration has scrapped the existing policy to phase out nuclear power plants. It has also proposed to develop future proprietary technologies, such as its own fourth generation SMR nuclear reactors, to strengthen ecosystem for nuclear industry.

Given that SMR will have a full-fledged market after 2030, it is necessary to develop the next innovative reactor that follows SMART set in the 2020s to preoccupy the market. In addition, it is essential to strengthen technology capabilities to enter the market after 2040 by developing the fourth-generation nuclear power plants, a major national strategic and security technology, as a game changer in the future energy market. The EU Parliament voted in 2022 to include nuclear power in the Taxonomy (green classification system). It proposed operating a radioactive waste disposal site by 2050 as a prerequisite to utilizing nuclear power plants. It is time for Korea to prepare for the nuclear power plant market in the future and for the sustainability of nuclear power plants.

Short-term(-5years)	Mid and long-term(5-10years)
• World-first safe, economical, and flexible manufacturing and core technology of SMR through Public-Private partnership	• Acquisition of SMR Standard Design Approval and global market entry • Development of the 4th generation reactor technology (production of hydrogen and process heat)

- Small Modular Reactor (SMR)
- Advanced nuclear system and waste management

5. Advanced bio-pharmaceutical

Advanced bio-pharmaceutical is designated as a new technology and industrial area that can overcome the limitations of existing bio-technologies through convergence with advanced technologies across the entire bio sector. As seen in the case of COVID-19, which caused significant economic and social damage around the world, this field is directly related to public health and life and is of high national security importance. It is also an area with great industrial potential, with the global population aging and the consequent increase in health demand rapidly expanding the scale of related markets.

The advanced bio sector is going through the industrial paradigm shift from synthetic drugs to bio-pharmaceuticals, such as gene and cell therapy, and from standard treatment to personalized treatment using AI and data analysis. In particular, there are attempts to increase production speed while reducing R&D and cost by utilizing advanced technologies, such as AI and robots. Changing technology paradigms in the bio sector and using high-tech technologies were considered vital to deriving high-tech bio-field technologies. In addition, as new infectious diseases are expected to arise in the future, Korea needs to secure capabilities to develop vaccines, just like other advanced countries that could develop vaccines on a new vaccine platform within months in after the outbreak of COVID-19.

Short-term(-5years)	Mid and long-term(5-10years)
• Obtaining a mRNA vaccine platform within several months • Building big data for Korean-specific genome and health	• Obtaining advanced country-level patents for genome and cell therapy (targeted chemotherapy) • Synthetic biology-based bio manufacturing and manufacturing advancement

- Synthetic biology
- Gene and cell therapy
- Vaccine and treatment of Infectious disease
- Analysis and utilization of digital health data

6. Aerospace and Ocean

Space technology is a technology that utilizes aerospace, aviation technology refers to a technology of design, manufacture, and flight for aircraft manufacturing, and ocean technology refers to a technology that secures new resources by exploring the marine environment. All aerospace and ocean are areas where advanced technologies, such as mechanical engineering, electrical and electronic engineering, and material engineering, are concentrated and utilized. As such, they have a broad impact on other industries. Although they have recently produced results, such as the launch of the Nuri and the expansion of civilian satellites, they still need to catch up with many technologies of advanced countries. Technology sharing would be difficult given the ongoing fierce competition between countries. Nevertheless, Korea must obtain these technologies for its military security.

Space transport where weight increase is expected requires a highly efficient staged combustion cycle engine, which burns fuel several times to create high thrust. It needs to secure space observation and sensing technologies through satellites to collect and utilize information independently, such as observation information, communications, and weather information in space. Considering the enormous economic value in the future, Korea must participate in the moon exploration that major countries are competitively engaging in. The aviation gas turbine engine is a technology acquired by six countries only around the world. It is necessary to secure Korea's own technology for the self-reliance of the aviation weaponry system and increased demand in the future. Marine resource exploration technology is a technology to explore and mine strategic minerals, such as rare earth, cobalt, nickel, and manganese, in the deep sea of the polar regions and ocean. Unlike land resources that have been extensively explored, it is in the early stages of development and can be a stable source of future strategic resources.

Short-term(-5years)	Mid and long-term(5-10years)
• Development of core technology for staged combustion cycle propellant rocket engine • Launching navigation satellite for high-precision GPS time	• Securing independent space exploration capability by developing next-generation projectiles • Development of independent core element technology for radar, optical observation, and moon exploration

- Large staged combustion cycle engine
- Advance aviation gas turbine engine and components
- Space observation and sensing
- Marine resource exploration
- Moon landing and surface exploration

7. Hydrogen

Hydrogen technology produces and stores hydrogen by changing water and organic materials and utilizes it as a carbon-free energy source, which will be vital to realizing carbon neutrality in major industries. To move from the current fossil fuel-centered energy system to a hydrogen economy, technologies throughout its lifecycle, such as production, storage, transportation, and utilization of hydrogen, are essential. Developed countries are competitively drafting a policy to preoccupy the future hydrogen market. Countries rich in renewable energy sources strive to solidify their status as hydrogen exporters by producing green hydrogen. In the future, hydrogen will likely be used as fuel in various fields, such as ships, automobiles, and aircraft, so it is necessary to establish an overall supply chain for production, transportation, and utilization.

Korea has high-level technologies in hydrogen applications, such as hydrogen electric vehicles and fuel cells, but Korea's competitiveness in the hydrogen production area is weak. For water electrolysis production, Korea depends on foreign countries for core materials, such as electrodes and separators. Even in applications with relatively high competitiveness, Korea still needs to rely on imports of core materials. In addition, hydrogen liquefaction and transportation technologies are monopolized by major foreign companies, such as the ones from the US and Germany, so there is a strong need for the localization of large-capacity hydrogen liquefaction technologies.

Short-term(-5years)	Mid and long-term(5-10years)
• Acquisition of proprietary water electrolysis technology for hydrogen production (1-2MW) • Development of commercial technology for transport of compressed gaseous hydrogen (400bar)	• Demonstration of quasi-commercial grade (10MW) water electrolysis system, localization of core materials and components, and building a commercial-grade liquefaction plant(5tons/day)

- Water electrolysis hydrogen production
- Storage and Transport of hydrogen
- Hydrogen fuel cell and generation

8. Cybersecurity

Cybersecurity technology protects systems, networks, data, and devices from cyberattacks and is essential for national, corporate, and public safety and trust. In particular, cyberattacks are increasing with the accelerating digital transformation. Also, as the attack targets and methods are diversifying, more robust response capabilities are becoming more critical. Global companies are more likely to be exposed to cyber threats with the spread of non-face-to-face and online-based digital services to the extent that they see "cyber attacks" as a threat in the post-COVID-19.

In cybersecurity, the subject and scope of security protection are rapidly increasing as the importance of data protection heightens with the digital transformation and the emergence of new industries, such as cloud, virtual convergence industry, and mobility. In particular, in next-generation network and cloud services, security capabilities should be bolstered through service native security technologies, not through existing security technologies. In addition, AI is projected to be an essential element in cybersecurity and lead the security paradigm shift with the advancement of AI-based security technology and the AI-based response to a service threat. Recently, there were cases in which the government and infrastructure were under attack by penetration of the HW/SW supply chain and modification of the source code. Therefore, securing the capabilities to detect and analyze vulnerabilities is necessary.

Short-term(-5years)	Mid and long-term(5-10years)
• Development of proprietary technology, such as AI-based security control and automatic response • Speedy analysis and response technology for ICT equipment and SW vulnerability (firmware)	• Self-sufficient cybersecurity system for future digital infrastructure (mobility, cloud, and 6G)

- Data and AI security
- Analysis and response of digital vulnerability (supply chain security)
- Network and cloud security
- New Industry and virtual convergence security

9. AI

AI technology acquires and utilizes results from high-dimensional judgment and analysis by emulating human's various information processing capabilities, such as cognition, learning, and inference. AI technology has a huge ripple effect across the entire technology and industry and is a key technology that supports the national economy. It is also widely used as military and civilian common technology. Currently, major countries recognize AI technology as the core of hegemonic competition, designate it as a national strategic technology, and engage in its development by making huge investments. In Korea, R&D investment, human resources, and sales in AI-related businesses are steadily increasing. In addition, AI is expected to become a game changer by improving decision-making speed and cyber warfare capabilities, efficient management of military supplies, and reduction of troop losses that strengthens the national defense capabilities. Besides, new international trade norms are also being discussed actively, with major countries, including the OECD members, establishing AI-related core values and ethics as norms.

With global companies injecting massive capital, investing in AI infrastructure alone has limitations in closing the gap with top-notch technologies. Therefore, it is necessary to secure strategic technologies in high-quality data and efficient computation. In addition, Korea must prepare for the future when the modeling and decision-making concepts will change entirely and improve product and service competitiveness, production volume, and production efficiency by applying AI in industry and innovation. How AI makes a decision must be explained well to people so they can understand how it makes a decision and perceives AI as safe and trustworthy.

Short-term(-5 years)	→	Mid and long-term (5-10 years)
• NG leading technologies like learning capability and enhanced applications • Development of AI killer solutions for industrial problem-solving (bio-pharmaceutical and, manufacturing)	→	• World-first AI technology superpower implementing highly sophisticated cognition,judgement, inference and decision-making capability

- Efficient learning, advancement of AI Infrastructure(SW/HW)
- Advanced AI modeling and decision-making (cognition, learning, and inference)
- Safe and trustworthy AI
- AI for industrial application and innovation

10. Next-generation communications

Next-generation 5G and 6G communication technology is to provide transmission speeds of up to 1 Tbps based on broadband frequency, low latency, intelligence, and satellites. It is an essential technology (infrastructure) that powerful countries and global companies need to cope with increasing data usage. It can be seen as a critical technology in the domestic supply chain. Major countries began competitively to build a network to expand the 5G market and intensively support international standards and R&D to preoccupy 6G. The US keeps China at bay by leading technology standardization with its allies and moves to exclude China from the global market. Currently, the private sector is promoting R&D, focusing on products and services and supporting national R&D projects simultaneously, but most of the core components and equipment are dependent on imports.

5G/6G is important diplomatically as it is a major cooperation topic on agenda at the Korea-U.S. summit. It is a technology that requires strategic development and support to preoccupy international standards. In addition, OpenLAN can be seen as an opportunity for Korean companies to change the Huawei-centered telecommunications equipment market structure. In this regard, attaining technologies is essential, and considering the supply chain instability, self-reliance of core equipment and components is also crucial. In addition, communication technologies, such as satellite payloads, need to secure competitiveness when global private companies enter the satellite communication market as a critical technology ushering in the 6G era.

Short-term(-5 years)	→	Mid and long-term (5-10 years)
• Core technology development, World-first 6G technology demonstration(1Tbps) • Early market entry with technology development of Open-RAN core equipment and components	→	• Early commercialization of world-first 6G and preoccupy standard patents • Demonstration of satellite technology using LEO satellite mega-constellation

5G advancement (5G-Adv)	6G	Communications components
• High-efficiency 5G·6G	• High-efficiency 5G·6G	• Open-RAN

11. Advanced robots and Manufacturing

As advanced technologies, such as AI and IoT, are applied to the existing robot field, robots are getting smarter rapidly. As a result, applications of robots in areas, such as medical, logistics, and safety are forecast to expand rapidly. In particular, with the development of AI, problem-solving skills, such as flexibility, adaptability, and versatility of robots, are increasing altogether. On the other hand, Korea has a high share of the manufacturing industry. It has the world's No. 1 robot density[11], a concept representing the number of robots per employee. However, the localization of core robot parts and SW is low, so advancing its robot technology capabilities is urgent. Global leading companies dominate core Robot parts and SW in the industrial structure, and localization is an important to resolve the instability in the global supply chain. Furthermore, the current manufacturing robot technology only applies to simple repetitive tasks, so the range of applications is narrow. Given that, it is necessary to upgrade robots' design, control, and high-level manipulation through convergence with AI technology. In addition, due to intensifying competition in the global manufacturing sector, the manufacturing industry's digital transformation using advanced ICT technologies, such as AI, big data, and 5G, is accelerating. In response, securing advanced manufacturing capabilities is becoming critical.

Short-term(-5years)	→	Mid and long-term(5-10years)
• Enhancing self-sufficiency of core components and SW, including sensors and motor modules • Expanding the ecosystem and de-regulation for high-growth industries (logistics and manufacturing)	→	• High-level autonomous control and mobility challenges, such as human-level robot hands • Advancing AI-robot convergence technologies, such as human interaction and collaboration

- Precision control, motor components, and SW of Robots
- Autonomous movement of robots
- Sophisticated autonomous control
- Human-Robot interactions
- Virtual Manufacturing

[11] Source, the Federation of Korea Industries, IFR, World Robotics 2021

12. Quantum

Quantum technology overcomes the existing limitations in data transmission and computation by applying entanglement and superposition, which are unique characteristics of quantum, to ICT. There are fields, such as quantum computing, quantum communications, and quantum sensing. When realized, quantum technology is expected to have a disruptive impact on the entire industries, including finance, IT, logistics, pharmaceuticals, and defense, based on its hyper-fast computing capabilities, overwhelmingly faster than before. In addition, quantum technology is like the two sides of a coin, neutralizing the existing encryption system with its computational power or strengthening security through quantum cryptography communications. Thus, competition between countries is fierce security-wise. Korea is a latecomer to quantum technology with a low level of technology and a lack of human resources and infrastructure compared to other advanced countries that have steadily invested for more than 15-20 years.

In quantum computing, Korea lags behind advanced countries in all fields, such as HW and SW. Still, Korea has a chance to catch up depending on the development of contested qubit implementation platforms. Korea has a competitive advantage in the field of quantum key distribution of quantum communication, and it also has some competitiveness in commercializing technologies for quantum cryptography communications Developing products at a global level and securing technological competitiveness are necessary to lead the quantum communication market in the future. Quantum inertial sensors are expected to replace existing sensors. Therefore, Korea must prepare for future demand across various industries, such as navigation and medical care.

Short-term(-up to5years)

- Closing the technological gap by building 50 qubit supercomputer
- Developing ultra-precision quantum sensors in cutting-edgy industries (semiconductor)

→

Mid and long-term(5-10years)

- Securing Korea-style quantum computing system with easy scalability
- Developing technologies for quantum relay and quantum internet for the trasmission of quantum data

- Quantum Computing
- Quantum Communications
- Quantum Sensing

3. Future Policy Direction

The Yoon Suk-yeol administration is preparing to (1) promote national strategic technology projects and (2) establish a mission-oriented strategic roadmap to foster the national strategic technologies.

First, the national strategic technology project is a large-scale public-private R&D project under the president aiming to create tangible results within five to seven years, including securing 'super-gap' and irreplaceable technologies. It will set goals with the industry and design it as a public-private

joint investment project in which companies participate. About ten projects will be launched over the next three years, from 2023 to 2025. Under the scheme, target technologies will be selected and planned as soon as possible, starting with next-generation nuclear power in 2023.

Second, we will establish a mission-oriented strategic roadmap that consolidates pan-ministerial strategies by clearly setting national missions and technology development goals. Through this, we plan to strengthen the government's strategic investment. In particular, Korea's technology level and market competitiveness differ in 50 key technologies, so we will differentiate the public-private role and strategy by technology, set clear missions and goals, and select and distribute R&D budgets accordingly. To this end, the investment system will also be supplemented by introducing a platform-type budget allocation method and improving preliminary feasibility study methods, such as as Fast Track.

In order to secure the national strategic technologies, comprehensive support measures must be prepared not only to make R&D investments but also to expand the foundation of strategic technologies, such as fostering human resources, international cooperation, and industry-academica-research institutes. Based on analysis and research on the status of human resources by strategic technology and diagnosis of industrial sites, measures will be prepared to secure core human resources and strategic partnerships, such as international joint research. The exchange of human resources will be strengthened by selecting major partner countries for each technology. In addition, it will designate and foster industry-academia-research institutes considering the technology level and its characteristics. The institutes will be specialized as university research institutes, corporate joint research institutes, government-funded research institutes, and regional technology innovation hubs, depending on the characteristics of the technology field.

Finally, the ruling and opposition parties have proposed a special law on developing national strategic technology as an institutional basis for continuously implementing policies to foster strategic technologies. It is now under deliberation at the National Assembly. It is necessary to enact it as soon as possible to select and manage the national strategic technologies systematically and to oversee the policy tasks as above, such as implementing related R&D projects, managing their performance, and training human resources.

Korea is at the inflection point where the global order is changing due to hegemonic competition between major powers. Just as the trend of international collaboration has continued for more than two decades, competition for technological supremacy will be the basic condition of our strategy for longer than expected. It is significant to prepare for a countermeasure called the "national strategic technology" in a time of change. Korea is standing on the threshold of uncharted territory. Korea must not let its guard down . It must make a success story with extensive investment and support for policy development to constantly discover and upgrade the "national strategic technology" without disruption.

KISTEP R&D and Beyond 2022

R&D Insight

Characteristics of government R&D investment direction and systematization of mission-oriented/leading strategic investment in 2023

10 Emerging Technologies to Contribute to 2030 NDC

KISTP Think 2022, 15 S&T Innovation Policy Agendas

Characteristics of Government R&D Investment Direction and Systematization of Mission-Oriented Leading Strategic Investment in 2023

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1. Entry to major S&T countries and government R&D investment direction in 2023 (draft)[1]

The year 2022 is very meaningful for Korea's S&T field and R&D investment system. Starting with the government R&D budget of KRW 2 billion in 1964 (1.66% of KRW 120.7 billion in the total government budget), national R&D investment is expected to reach KRW 100 trillion this year. Korea has become the world's 5th largest R&D investment country (OECD, 2021) after the US, China, EU, and Japan, which are major countries in S&T. The world innovation index of the country (UN WIPO, 2021) also rose to fifth place, following Switzerland, Sweden, the US, and the UK. In addition, Korea maintained a high technology trade balance ratio (1.5) in the high-tech industry among major countries. Its classification has changed from a developing country to an advanced country according to the UNCTAD[2] standard. The expansion of R&D investment and the improvement of S&T performance were possible thanks to the efforts of S&T researchers and cooperation between industry-academia-related innovators in the process of changes in the economic and social environment and industrial development. The purpose of R&D investment is to achieve economic and social development and national innovation. According to the 2021 IMD[3] World Competitiveness Yearbook, Korea ranks second in the world in science infrastructure and 17th in technology infrastructure but 23rd in comprehensive evaluation rankings. Based on the World Bank, Korea's national GDP ranks 10th in the world, but its per capita GDP ranks 27th. It is time for Korea to focus on securing economic and social development at the level of leading countries based on R&D investment and S&T achievements on the scale of advanced countries. Also, it should promptly shift to a leading R&D investment and strategic innovation system.

[1] The Science and Technology Innovation Headquarters of the Ministry of Science and ICT presented the "2023 Government R&D Investment Direction and Standards (draft)" to the Steering Committee of the National Science and Technology Advisory Council for vote; deliberated/coordinated the budget for the following year and submitted it to the Ministry of Economy and Finance; and finalized the government budget plan

[2] Country classification of the UN Conference of Trade and Development A/C/D (Developing Countries), Group B (Developed Countries)

Table 1 Changes in national R&D investment scale and economic growth in Korea

National R&D investment scale	One trillion won era (1985) 1,155.1 billion won	10 trillion won era (1996) 10.878 billion won	50 trillion won era (2012) 55.4501 billion won	80 trillion won era (2018) 85.7287 billion won	100 trillion won era (2022) 1,021,220 billion won (estimated)
GDP per capita (thousand dollars/ PPP)	7.5/ 7.3 (World/Korea)	8.6/ 20 (World/Korea)	13.8/ 32.4 (World/Korea)	14.5/ 36.1 (World/Korea)	16.19/ 44.5 (World/Korea (2021))
Financial resources (100 million won) (government/ private/foreign)	2,229/ 9,302/ 19	28,506/ 80,137/ 136	138,220/ 414,377/ 1,902	183,630/ 657,027/ 16,629	297,770 (2022) / 723,450 [4]
Research personnel (people)	41,473	132,023	401,724	514,170	558045. (2020)

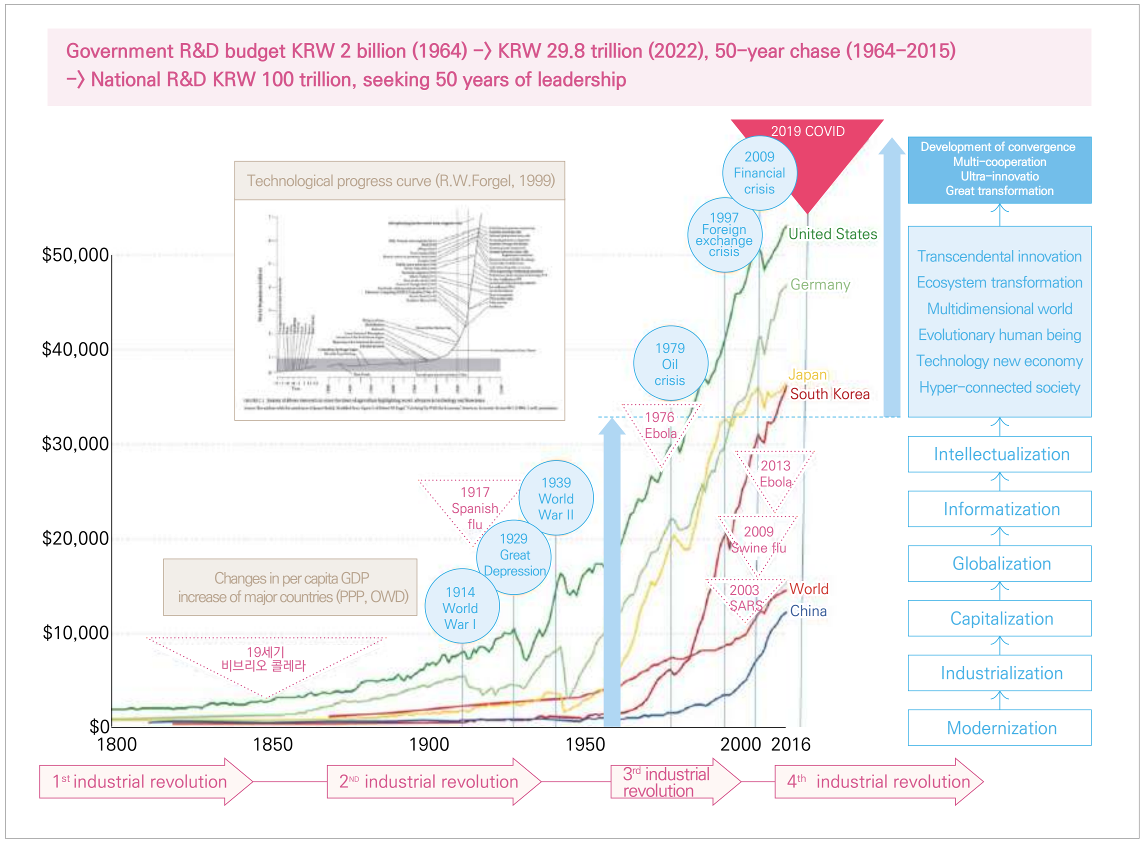
Table 2 Ranking of R&D investment and major innovation performance of major countries

Indicators and Indices	The US	China	Germany	Japan	Korea	The UK	Switzerland	Sweden
GDP for one year (2021, IMF[5]/WB)	1	2	4	3	10	5	18	22
GDP per capita (2021, IMF/WB)	5	59	17	24	27	21	3	11
National R&D investment (2020, OECD)	1	2	3*(EU)	4*	5	7	11	14
World Innovation Index (2021, UN WIPO[6])	3	12	9	13	5	4	1	2

* The EU that includes Germany ranks third/Japan in fourth. By individual country, Japan ranks third and Germany in fourth (PPP$/ Purchasing Power Parity)

[3] IMD (Swiss International Management Development Institute) announces the ranking and field competitiveness for national competitiveness evaluation through the World Competitiveness Yearbook. Korea's 2021 comprehensive evaluation results are 23rd out of 64 countries subject to evaluation

Figure 1 Modern global crises and paradigm shifts, and changes in per capita GDP of major countries (PPP/Purchasing Power Parity)



The "Government R&D Investment Direction and Standard Plan (Science and Technology Innovation Headquarters, March 2023)" to formulate and adjust the government R&D budget for 2023 has been finalized. According to the National Fiscal Management Plan (Ministry of Economy and Finance, August 2021), the government R&D budget for 2023 is KRW 32.3 trillion, an increase of about 8.5% compared to KRW 29.8 trillion in 2022. The Government R&D Investment Direction is set under priorities and investment areas for each policy and technology sector by analyzing the realization of economic and social goals through R&D and the demand for the national innovation system. The budget for 2023 is finalized through the decision of the budget planning direction at the National Fiscal Strategy Meeting presided over by the President; the government R&D budget review by the Science and Technology Innovation Headquarters; the submission of the government budget bill by the Ministry of Economy and Finance; and the resolution of the National Assembly. The Government R&D Investment Direction (draft) for 2023 is

[4] Estimated by applying the average annual growth rate of 5% of private R&D investment between 2015 and 2020 to the private R&D investment in 2020 (KRW 68.9 trillion)

[5] INTERNATIONAL MONETARY FUND (IMF), an international financial organization created in 1945 by raising funds from developed countries

[6] UN World Intellectual Property Organization evaluates intellectual property protection and knowledge-based innovation capacity

the people-centered strategic R&D investment, which provides directions for nine major investments in the top 4 areas to expand future growth potential, improve people's quality of life, and lead the era of global technological supremacy and great transformation. Moreover, emphasis was placed on strategic investment and balanced budget allocation for sustainable national development and improvement of people's quality of life, such as rapid recovery from economic and social shocks caused by COVID-19, leading competition for global technological supremacy and digital transformation, the expansion of R&D on climate change and transcendent social problem solving, health and security, jobs and regional innovation.

Figure 2 Nine priority directions in 4 areas of government R&D investment in 2023 and advancement of investment system

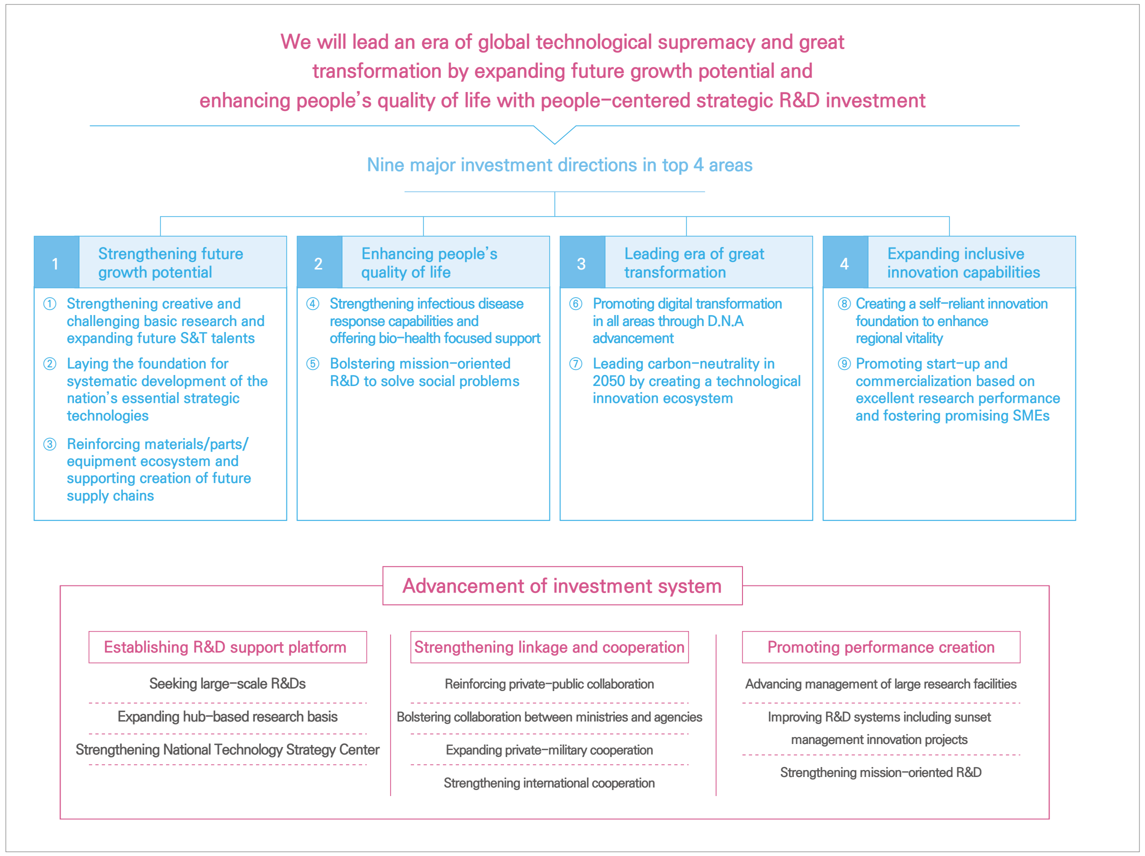
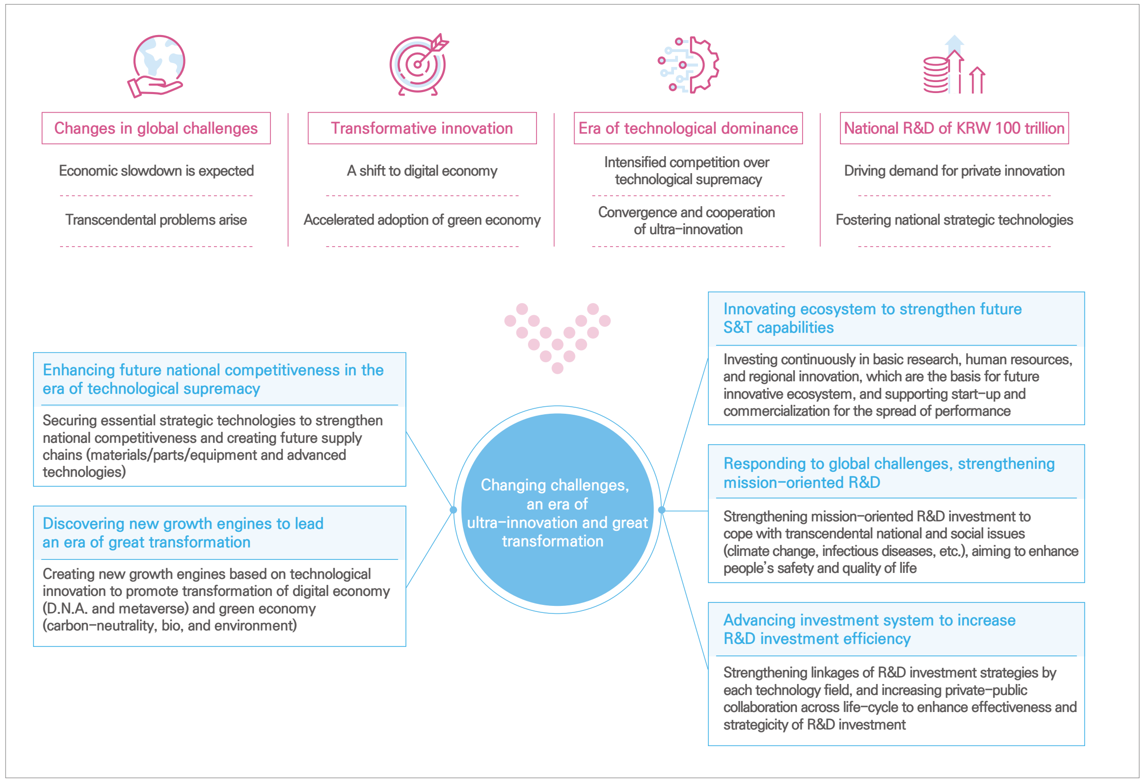


Figure 3 Key points of establishing government R&D investment direction and systematizing investment system in 2023



2. Leading R&D investment to turn crisis into opportunity and strategic allocation of the government R&D budget

The COVID-19 pandemic, which broke out in January 2020, not only threatened the safety and survival of the people but also led to economic recession, a decline in face-to-face activities, job loss, and a decline in economic growth rate. Complex crises and transcendent problems in the global economy and society are increasing due to the reorganization of supply chains and geopolitics/geopolitical conflicts between countries. The UN, OECD, and major countries are expanding the role of S&T and R&D investment for a rational response to these transcendent problems, strategic opportunity conversion from complex crises, and sustainable development. In addition, since the global financial crisis in 2008, mission-oriented R&D investment has been emphasized, such as the government's role and intervention in securing growth engines and innovation activities to overcome the global economic downturn.

Table 3 Key investment items for each of top 4 areas of government R&D in 2023 (other than government R&D investment direction and standard proposal in 2023)

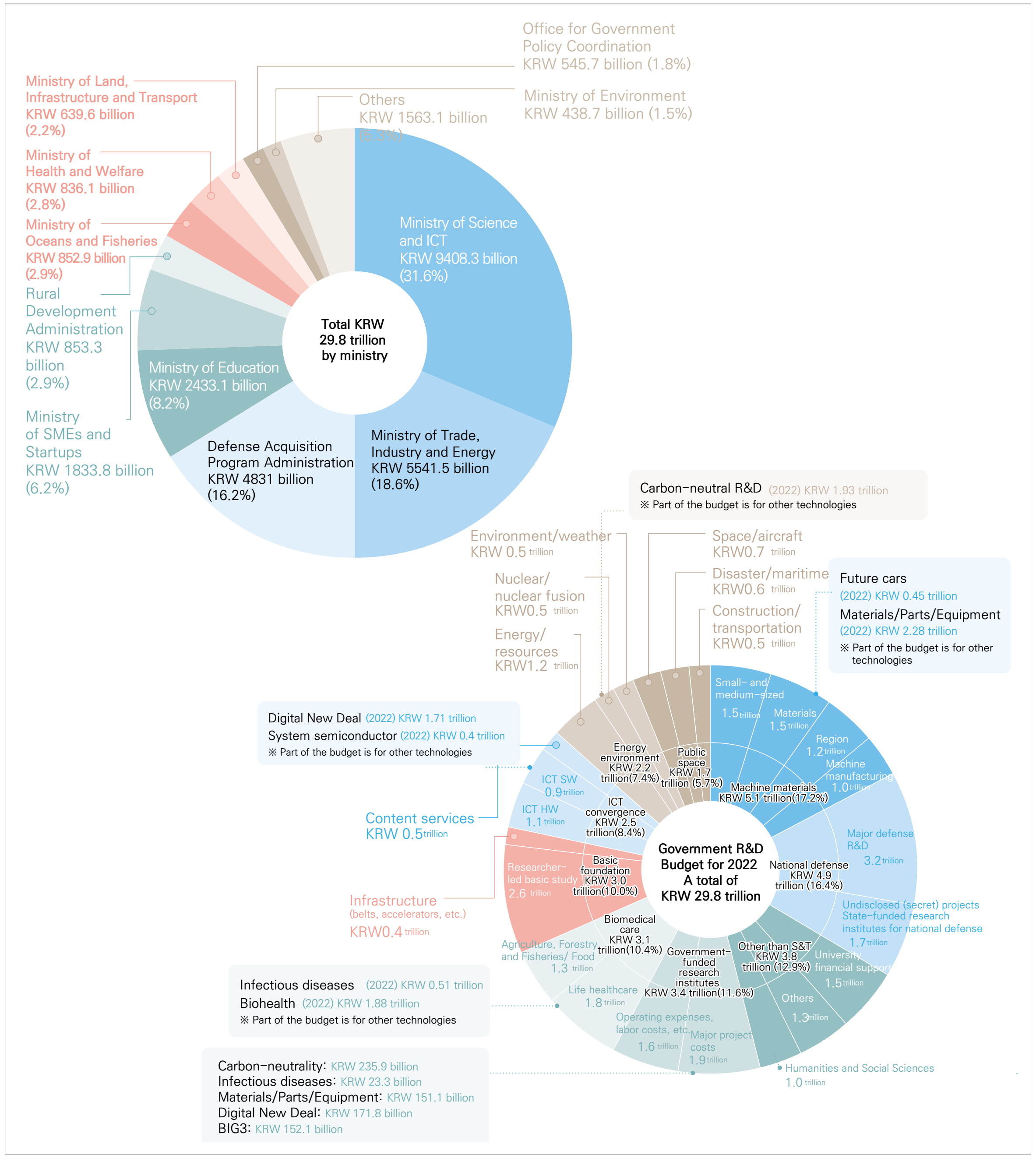
(Field.1) Era of competition for global technological supremacy, strengthening of future growth potential	
Creative and challenging basic research and expansion of future talents	Respond to changes in the basic research environment, such as a decrease in the school-age population and the burden of researchers' knowledge accumulation; strengthen support for the transition to an advanced research ecosystem; and support the continued growth of young and female researchers and the next generation of academics that will be the leaders of future S&T innovation
Laying the foundation for the systematic development of essential national strategic technologies	10 strategic technologies (AI, 5G/6G, advanced biotechnology, semiconductor/display, secondary battery, hydrogen, advanced robot/manufacturing, quantum, aerospace/aircraft, cybersecurity, national defense) investment and investment system to respond to competition for global technological supremacy support
Response to materials/parts/equipment ecosystem and supply chain	Continue investment to stabilize supply chain and technology independence for materials/parts/equipment, and support core material technology development to lead future industries in promising fields (enhancement of ecosystem, securing original technology such as future leading items, etc.)
(Field.2) Improving people's quality of life by guaranteeing a safe and pleasant life	
Infectious disease response and bio-health focused support	Focused investment in innovative technologies based on technological convergence and integration (vaccine treatment, mRNA platform, digital health care, etc.)
Expansion of mission-oriented R&D to solve social problems	By strengthening social problem-solving R&D based on specific social problems, creating results that people can feel and contributing to the improvement of quality of life (response to super-aged society, disaster safety, living/environment, public order/firefighting R&D, etc.)
(Field.3) Leading innovation based on S&T in the era of great transformation	
D.N.A advancement promotes digital transformation in all areas	Advancement of D.N.A technologies such as 5G, AI, and cloud, and promotion of digital transformation to all industrial areas based on convergence and diffusion (strengthening D.N.A ecosystem, fostering non-face-to-face industry, SOC digitization, metaverse, etc.)
Creating a technological innovation ecosystem leading carbon neutrality in 2050	In connection with strategic roadmap for the carbon-neutral innovative technology, focus on key technologies that require achievement of NDC goals and rapid application and spread to industrial sites (industry/transportation innovation, renewable energy conversion, low-carbon ecosystem, climate adaptation/absorption and infrastructure, etc.)
(Field.4) Strengthening inclusive innovation to expand the foundation for innovation	
Creating a self-reliant innovation foundation to enhance regional vitality	Creating good jobs through regionally tailored R&D, such as cultivating research institutes with local universities and cooperation in ultra-wide areas (mega-cities), creating a foundation for regional self-reliance innovation (expanding the foundation for innovation in local industry, academia, and research, fostering strategic and key industries, fostering local talents, etc.)
SME innovation support, start-up commercialization promotion	Supporting the growth of technology start-ups and start-up companies linked to research results, and accelerating the spread of research results by increasing the success rate of technology commercialization based on a customized support system (innovation and start-up of SMEs, technology commercialization and innovative procurement R&D, etc.)

The Government R&D Investment Direction for 2023 was established with a focus on new challenges, ultra-innovation, and leading strategies for great transformation in order to effectively respond to the crisis of rapid global environmental change and create strategic opportunities for innovation competition among major countries. The primary investment directions for this goal are ① Creative and challenging basic research and expansion of future talents, ② Laying the groundwork for systematic development of essential strategic technologies for the country, ③ Response to the materials/parts/equipment ecosystem and supply chain, ④ Response to infectious diseases and intensive support for biohealth, and ⑤ Resolution of social problems, ⑥ Expansion of mission-oriented R&D for D.N.A advancement, promotion of digital transformation in all areas by the advancement of D.N.A, ⑦ Creation of an ecosystem for technology innovation, leading to carbon neutrality by 2050, ⑧ Establishment of self-reliant innovation base to enhance regional vitality, and ⑨ Support for innovation of SMEs, promotion of start-up commercialization, etc. Looking at the key innovation plans, promotion strategies, and R&D investment programs of major S&T countries, they can be classified into strengthening innovative research capabilities, expanding economic growth engines, and improving the quality of social life according to the purpose of R&D budget investment. The main R&D budget according to these investment directions subdivides the R&D programs and unit, detailed, specific projects of 36 ministries, agencies, and offices into key investment policies and technology areas. Budget requests and project details for new/continued projects are submitted to the Science and Technology Advisory Board. It is reflected through the review and consultation of the budget deliberation expert committee under the Ministry of Science and Technology and the final deliberation by the R&D Investment Deliberation Bureau of the Science and Technology Innovation Headquarters. Afterward, the Ministry of Economy and Finance conducts an integrated review of the general R&D budget, reflects it in the following year's government budget, and finalizes it in the plenary session of the National Assembly. As for the direction of investment, the R&D project review and budget deliberation are carried out according to the investment strategy by classifying major investment policies centered on economic and social purposes and joint R&D science and technology fields between policy areas as transversal. R&D project budgets in key technology areas are reviewed and reflected based on the suitability of the investment direction, strategic feasibility of the budget requirements, and contents of the technology-related projects.

Table 4 Government R&D investment direction by technology field in 2023 (other than government R&D investment direction and standard proposal in 2023)

Technology field	Main content
ICT·SW	• **(Investment direction)** Securing leadership in the essential strategic technology field, realizing non-face-to-face and virtual worlds • **(Efficiency)** Improving R&D operation and linkage/usability of commercialization • **(Specific technology fields)** AI semiconductor, 6G, quantum, next-generation AI, metaverse, blockchain, cloud, etc.
Life·Health care	• **(Investment direction)** New drug development based on AI and data, support for research and foundation for the life-cycle of the biohealth industry • **(Efficiency)** Accumulation of biodata, advancement of AI technology grafting industry, development of innovative platform to respond to infectious disease crisis • **(Specific technology fields)** Stem cell, brain research, synthetic biology, mRNA vaccine, health care, etc.
Energy·Resources	• **(Investment direction)** Innovative carbon reduction technology and energy efficiency, safety and utilization of nuclear power, stable securing of resources • **(Efficiency)** Improving the strategic nature of small and medium-sized businesses related to carbon neutrality, linking and cooperating with ministries • **(Specific technology fields)** Renewable energy, hydrogen production/storage/transport, low-carbon process, SMR, nuclear fusion, re-manufacturing, etc.
Materials · Nano	• **(Investment direction)** Developing eco-friendly materials and processes for carbon neutrality, advanced investment in response to GVC • **(Efficiency)** Inspecting investment priorities, responding to material policy demand, cooperation-based R&D • **(Specific technology fields)** CCUS materials, future leading items, R&D core items, ultra-low-power high-performance devices, etc.
Machinery · Manufacturing	• **(Investment direction)** Environment-friendly/digitalization, support for SMEs • **(Efficiency)** Customized digital transformation, inter-departmental joint project planning, organic collaboration • **(Specific technology fields)** Eco-friendly transportation/plant/construction machinery, digital engineering, autonomous driving, smart manufacturing, robots, etc.
Agriculture, forestry, and fisheries · Food	• **(Investment direction)** Securing core technologies across the value chain (breeding, production, distribution/consumption), corporate-led convergence R&D • **(Efficiency)** Pan-governmental cooperation model for public-private partnership, convergence of on-site linkage/utilization technology • **(Specific technology fields)** Facility/field smart farm, advanced fishery industry, distribution/logistics advancement, microbiome, etc.
Space · Aerospace · Marine	• **(Investment direction)** Securing core technologies and expanding base/infrastructure, digital transformation in the marine field, development of carbon-neutral technology • **(Efficiency)** Performance utilization/collaboration, field-oriented institutional improvement • **(Specific technology fields)** Satellite development, next-generation engines, UAM, aviation parts industry, smart ports, eco-friendly ships, etc.
Construction · Transportation	• **(Investment direction)** Transportation system intelligence demonstration technology, smart construction demonstration technology • **(Efficiency)** System/infrastructure improvement, linkage/collaboration between ministries • **(Specific technology fields)** BIM design technology, spatial information digitization, smart city, level 4 autonomous driving, smart logistics, etc.
Environment · Meteorology	• **(Investment direction)** R&D centered on creating a pleasant and safe living environment and solving problems • **(Efficiency)** Performance analysis and utilization, linkage with private investment, R&D support tailored to field demand, multi-agency R&D • **(Specific technology fields)** Fine dust reduction, ICT-based workplace management, waste plastic recycling, water supply and sewerage function innovation, etc.
Foundation · Base	• **(Investment direction)** Support for individual/group basic research, nurturing future S&T innovative talents • **(Efficiency)** Promoting stable support, systematic management of large-scale research facility construction projects • **(Efficiency)** Promoting stable support, systematic management of large-scale research facility construction projects
National defense	• **(Investment direction)** Securing core power for weapon system development, expanding industry, academia, and research participation • **(Efficiency)** Improving the system and strengthening management, expanding strategic technology investment, and expanding the basis for private participation • **(Specific technology fields)** State-of-the-art command and reconnaissance assets, air power reinforcement, maritime deterrence capabilities, precision strikes, essential strategic technologies, etc.

Figure 4 Investment status of government R&D budget by department and key areas in 2022 (2022 R&D Budget Proposal)



The annual investment direction establishes a macroscopic budget allocation structure based on the Science and Technology Basic Plan, mid- to long-term R&D investment strategy, and mid-term financial plan. The main points of the investment direction and the priority strategy are set by analyzing the changes in the economic, social, and S&T environments, such as the global environment, R&D investment trends in major countries, S&T policies and competition, and changes in state affairs and fiscal strategies. In addition, budget allocation and project structure direction for each field are established by reviewing the approval of the Science and Technology Ministers' Meeting for R&D investment and promotion strategy and the investment priorities of ministries. The government R&D project budget in 2022, based on the investment direction in 2022, was KRW 29.77 trillion, an increase of KRW 2.4 trillion (8.8%) from the previous year, and it was earmarked as 4.9% of the total government expenditure of KRW 607.7 trillion. The trend of total government R&D expenditure increased by KRW 10.7 trillion until 2022 from KRW 19.1 trillion in 2016, showing a high rate of increase since 2020. The government's key R&D investment items in recent years are self-sufficiency of materials, parts, and equipment to respond to Japan's export regulations in 2020, promotion of non-face-to-face technology and biomedical services to overcome COVID-19 in 2021, a Korean version of the New Deal, etc., strategic technology fields for recovery and inclusion, and growth. The Government R&D Investment Direction in 2023 includes measures to improve the efficiency of the investment system, focuses on the strategization and systematization of investment, such as promoting large-scale R&D across ministries, expanding hub-oriented research bases, strengthening the National Technology Strategy Center, and bolstering public-private collaboration and inter-ministerial collaboration.

Table 5 Changes in government R&D investment direction in recent years and system efficiency direction (other than government R&D investment direction standard)

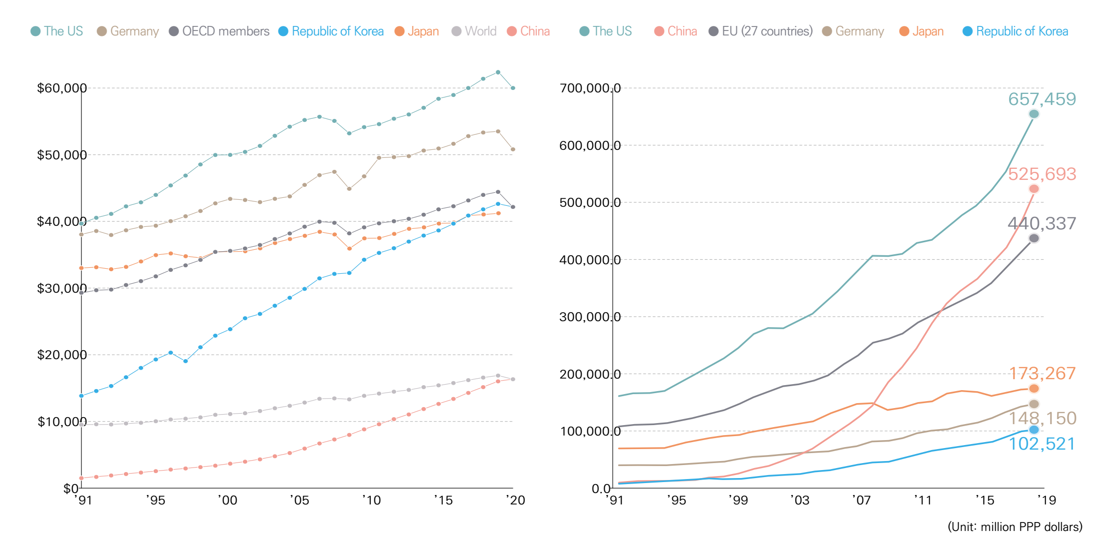
2020 (9 major focuses in top 3 areas)		2021 (11 major focuses in top 4 areas)		2022 (10 major focuses in top 4 areas)		2023 (9 major focuses in top 4 areas)	
S&T capabilities	Reinforcing basic research, strengthening industry-academia-research capabilities, nurturing talented people	Innovation capabilities reinforcement	Researcher-centered creative challenge research, public research institutions, local SMEs	Crisis response capability reinforcement	Overcoming the infectious disease crisis, materials/parts/equipment	Future growth potential reinforcement	Basic research and expansion of talents, the nation's essential strategic technology, response to materials/parts/equipment supply chain
Improving economic vitality	4th industrial revolution growth achievement, job creation, regional innovation	Growth potential expansion	4th industrial revolution, new industrial growth, innovative talent development, technology commercialization	Economic recovery enhancement	Three major industries (bio, future car, semiconductor), D.N.A (data, network, AI)	Quality of life	Infectious disease response capabilities, bio-health support, social problem solving
		Quality of life	National health life, safe life, sustainable environment	Opportunity creation	Carbon neutral future core technology	Leading the great transformation innovation	D.N.A advancement and digital transformation, carbon neutrality
Quality of life	Public health, disasters, climate environment	Crisis response	Post-corona reinforcement of response capabilities	Inclusive innovation capabilities	Basic research, development of talents, small and medium-sized business area, start-up and technology commercialization	Inclusive innovation reinforcement	Enhancing local vitality, promoting SME innovation and start-up commercialization

Investment system efficiency plan by year							
Strengthening investment strategy	R&D package investment, policy investment performance connection	Enhancing efficiency	R&D package investment, policy investment evaluation connection	Sharing connection cooperation sharing	Strengthening public-private cooperation, performance-oriented multi-departmental support	R&D support platform	Promoting pan-governmental large-scale R&D, expanding hub-oriented research base, and strengthening the National Technology Strategy Center
Investment efficiency	Reinforcement of large-scale projects and inspection of planning and execution	Autonomous collaborative base	Collaboration with ministries, goal-oriented pan-governmental project management, field-oriented research management system	Promoting performance creation	Cross-ministerial relay, innovation procurement, and social problem solving	Strengthening linkage cooperation	Strengthening public-private cooperation, enhancing cooperation between ministries, expanding cooperation between civilian and military forces, and strengthening international cooperation
Strengthening self-responsibility	Innovation in sunset management, strengthening autonomy and responsibility			Enhancing investment effects	Comprehensive project management, performance management of materials/parts/equipment, and policy linkage	Promoting performance creation	Advancing large-scale research facility management, improving R&D systems such as sunset management innovation projects, and strengthening mission-oriented R&D

3. Expansion of strategic R&D investment and mission-oriented R&D programs in major countries

The global economic and social crisis caused by COVID-19 shows some signs of recovery, but the year-on-year economic growth rate is declining. The global economic growth rate in 2022 is expected to be 4.4%, but the face-to-face economy continues to contract, and the growth of the real economy remains stagnant. The risk of uncertainty and complexity in the global economy and society are increasing, such as more frequent disasters due to the spread of corona mutations and climate change, bottlenecks in raw materials and supply chains due to geopolitical disputes, and reorganization of global value chains stemming from competition for technological supremacy. Since 2015, the UN has newly set disaster risk reduction[7] and sustainable development goals[8] and global cooperation. and included developed countries as major target countries. In particular, it recommended the establishment of insights and methods, problem-solving and evidence-based policies through S&T while emphasizing the connection between S&T and policy, such as sharing S&T information knowledge and establishing a multidisciplinary research system for complex risks. This is believed to have recognized the limitations of narrow cooperation, segmentation systems, fragmented activities, and non-scientific approaches in responding to and solving transcendent problems such as global crisis and climate change in economy and society due to global risks such as pandemics. Amid these global environmental and policy changes, and the expansion of the role of S&T, R&D investment in major countries continues to increase. As of 2019, Korea ranks first in the world in terms of government R&D investment as a percentage of GDP and second in the world in terms of total R&D investment as a percentage of GDP. The average annual growth rate of the total R&D budget over the past five years (2015-2019) was 7.61% in Korea, 7.68% in China, 5.04% in the US, and 5.52% in the EU. As for major countries since 1991, the per capita GDP has grown steadily in Korea and the US. However, Japan and OECD member countries have shown low growth rates. As for trends in national R&D investment, the gap in investment scale and cumulative investment between the US. and China and Korea, Japan, and Germany is widening significantly. The gap between the US. and China is continuously narrowing. Given the trends, it is expected to see overheating competition for supremacy in S&T between the US. and China, reorganization of the technology supply chain between Korea, Germany, and Japan, expansion of mission-oriented policies and R&D projects, and strengthening of technology strategy projects.

Figure 5 Changes in per capita GDP growth and national R&D investment of major countries since 1991 (OECD/OWD et al., 2021)



[7] United Nations Office for Disaster Risk Reduction (UNDRR): Emphasize the connection between concepts such as climate change and sustainable development, and disaster risk reduction, and shifts the paradigm from disaster to disaster risk.

[8] Sustainable Development Goals (SDGs): Define global threats in economic, social, and environmental terms, and suggest 17 goals including poverty, health, education, employment and jobs, industrialization innovation, inequality reduction, climate change response, and global cooperation.

Figure 6 Share of investment by economic and social purpose in government R&D budget of major countries in 2019 (OECD MSTI, 2021)

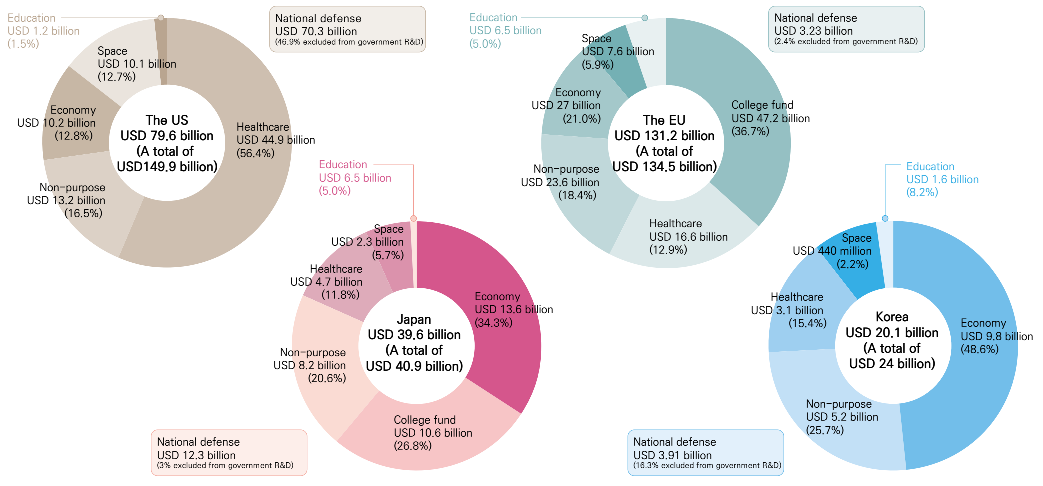


Table 6 Legislation of initiatives for strategic R&D investment in major countries and changes in strategic organizations

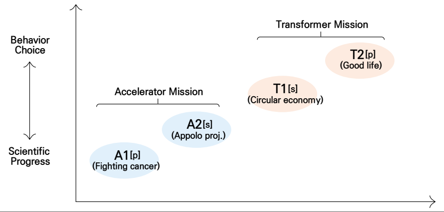
Name of country	Response system of major countries
The US	• The CHIPS Act, US Innovation and Competition Act (USICA), National Defense Authorization Act (NDAA), Infrastructure Investment Jobs Act (IIJA), Homeland Security/Political Affairs Regulations, China Challenge Response Act (2021), etc. Strategic investment in semiconductor/battery/rare earth/pharmaceutical supply chain • (Endless Frontier Act/NSF Future Act) Federal government departments (NSF, DOC, DOE, NASA, etc.) reinforce strategic nature and invest about USD 120 billion in core technologies over the next five years, and establish a technology innovation bureau within NSF (10 core technologies/ social problem-solving R&D)
China	• (14th Five-Year Plan) Enhancement of S&T capabilities through strategies to secure self-sufficiency and self-reliance in S&T and internal growth engines • (S&T Innovation) Sustainable innovation-led development, a powerhouse of science education talents, new national system, reform of S&T system, 10-year action plan for basic technology, etc.
The EU	• (Horizon Europe) Enhancing GDP growth, job creation, and research capabilities in the key policy directions for European research and innovation • Global challenges in excellent science and key technologies, strengthening of industrial competitiveness, limit-breaking R&D and creation of an ecosystem, etc.
Japan	• (Basic Plan for S&T Innovation) Occupying a global leadership and realizing Society 5.0, the convergence of natural sciences and humanities and social sciences • Establishing an organization in charge of economic security in the Cabinet Office, and the "Important Technology Research and Development Council (tentative name)" composed of related ministries and agencies, and researchers (2021)
Germany	• Reinforcing technology sovereignty in key technology fields, establishing the "Technology Sovereignty Committee" supervised by Bundesministerium für Bildung und Forschung (BMBF) (2021.9)
France	• Reinforcing national competitiveness through technological innovation, establishing the "Innovation Committee" (2019.11), and financial support of 250 million euros from the Innovation Industry Fund
The UK	• Superpower in S&T, an announcement of establishing the Science and Technology Strategy Office (OSTS) under the National Science and Technology Council (NSTC)/support organization of the Prime Minister's Office (2021.6)

Table 7 Major countries' S&T innovation plans and strategic R&D investment program projects (OECD/KISTEP reports, etc.)

Name of country	Response system of major countries		
The US	· US innovation strategy (innovation-based investment, -> promotion of private innovation activities incentives for national innovation) · NIH[9] Next-Generation Researcher Initiative (new, mid- level researcher support · NSF Top 10 Big Ideas Project (Future initiative, AI/robot/IoT/quantum/data, etc.) · Small and medium business innovation research program (federal institution)	· Artemis Project, Nano Initiative · Defense DARPA, national AI R&D strategic plan · Quantum Information Science Network Strategic Vision (Quantum Science Policy Department of Science and Technology Policy Office), Manufacturing Innovation Network Strategic Plan (Advanced Manufacturing Competitiveness and Technology Capability Enhancement), Networking and IT R&D Program · Manufacturing USA (R&D, research institute support)	· ARPA-H, NIH COVID-19 research strategy plan, precision medicine promotion plan, federal medical IT strategy · Air and energy R&D action plan, Environmental Protection Agency's strategic plan, agricultural food research initiative · Support for NIH Allergy and Epidemiology Research Center · All of US research program, Air and Energy research (air quality, air pollution, air, etc.)
China	· S&T development plan (basic science, frontier technology research reinforcement, etc.), establishing national innovation body, action plan for 10-year basic research, mid- to long-term S&T development plan 2035 (BT, IT, ET, NT, energy, advanced technology, etc.) · National innovation-led development strategy (industrial technology, source, region, civil-military convergence, subject, manpower, etc.), 13th 5-year S&T development project	· Tasks of National Science and Technology Innovation Plan (leading, source,innovation space, start-up, system reform, etc.) · Tasks of National Strategic Emerging Industry Plan (innovation strategy,market, core technology, system formation, digital, AI, robot, new material, new energy, environment, aerospace, strategic industry, bio, low carbon, expansion of global influence, etc.), Chinese manufacturing powerhouse business, etc.	· Emergency management department under the State Council · National Health Commission Program · Green low-carbon and carbon-neutral policies · Health and hygiene development plan, Health China 2030 · Construction of Natural disaster assessment platform · Projects for disaster prevention and reduction science and technology · National comprehensive disaster prevention plan 2020
The EU	· (The 9th FP Horizon EUROPE) EU Research Committee, Marie Curie Action, European research infrastructure (mission-oriented challenge innovation research, manpower training, foundation, etc.) · Public-private research infrastructure strategy forum/consortium · The UK. (doctor training, knowledge transfer partnership, facilities maintenance (diamond light source), etc. · Germany (high-tech strategy, professional manpower base, etc.)	· Future emerging technologies (bio, data, system, green, nano, nerve, quantum, robot, new materials) · Building infrastructure and industrial technology leadership (manufacturing robots, advanced materials, life science, nanoelectronics, AI, quantum, security, space, etc.) · Public-private partnership (PPP, top-down research, etc.) · Industry 4.0 platform (digitalization of value chain)	· Health, demographic change and welfare, safety and cleanliness Energy (sustainability, disease/health/medicine, decarbonization, response to global warming, etc.) · Horizon Program (Health sector, research cooperation, Health industry, partnership, life science blue sky research, etc.) · Energy innovation program (energy security, etc.)
Japan	· New research system (data, DX, infrastructure, etc.) · Society 5.0 SIP[10] 2nd term (2018-2022, strategic innovation program, approximately 50 billion yen per year, etc.), strengthening research and R&D capabilities (challenging opportunities for new researchers, sources, career, talent development, etc.), technologies for key innovation areas (AI, bio, quantum, materials), and applied technology	· Promoting SIP public-private cooperation and challenge programs · PRISM[11] (reinforce public-private investment, AI/IoT/big data, etc.) · ImPACT[12]. (Challenge Innovation Project, brain/nuclear/bio/optical/quantum/robot, etc.), key technology planning strategy · MOONSHOT[13] (disruptive innovation task, lunar exploration, brain, diseases, new AI and robot technologies	· 2nd SIP (coronavirus infectious disease response and public medical establishment, etc.), natural disaster countermeasures · Reinforcing response to public health crises (diagnosis, treatment, and vaccines) development, R&D of equipment, etc.) · Establishing a strong social and economic structure (implementation of a decarbonized society, promotion of innovative environmental innovation)
Korea	· Government R&D innovation plan (leading R&D, strategic investment, etc.) · Human/Regional Balanced New Deal (Human Resource Development and Expansion/ Support of Regional and Local Government-led Projects) · Basic research project implementation plan (young researcher support and early research environment), public-private cooperation SW talent development measures (SW talent development policy promotion)	· The nation's essential strategic technologies, Digital New Deal (digital convergence, hyper-connected new industry, SOC digitalization) · Material parts equipment R&D advancement, innovative growth BIG3 industry intensive fostering plan, space development promotion plan, ICT source R&D business implementation plan · Convergence technology development project implementation plan, etc.	· National infectious disease crisis response technology development (infectious disease crisis overcome technology development and vaccine localization) · Strategies for promoting carbon-neutral technological innovation (carbon-neutral new industries, high-carbon process product replacement, source technology) · Green New Deal (GHG measurement and evaluation system, green ecosystem establishment support)

Table 8 Concepts and types of mission-oriented innovation policies and examples of approaches to R&D systems (EU/OECD/except Germany)

Name of country	Response system of major countries
Mission -Oriented Program (MOP)	• Intensive investment of national budget resources to achieve specific goals in the form of government R&D projects in developed countries in the 1960s and 1970s ※ US Manhattan Project (atomic bomb development), Apollo Project (moon exploration), Airbus Project, Concorde Project (high-speed aircraft development) ※ Weinberg's (1967) definition of mission-oriented R&D is "Big Science deployed to meet big problems". • R&D projects returned to market based on corporate demand (MOP: Mission Oriented R&D Program) as questions were raised about the validity of the government's direct intervention in large-scale research or innovation projects in the 1980s
Mission -Oriented Innovation Policy (MOIP)	• Due to the global financial crisis (2008) around the 2010s, the necessity and importance of the government's role in R&D and innovation activities was raised again[14] ※ Kuittinen (2018) presents specific goals, deadlines, and large ripple effects as characteristics of a new mission-oriented innovation policy (MOIP: Mission-Oriented Innovation Policy), crossing the boundaries between fields

Definition of mission	Type of mission
• Used to set the direction of innovative efforts • Aiming for bold challenges in the social, economic, and scientific fields • Expansion beyond traditional S&T policies to the realm of coordination of interests ※ Classification criteria: ❶ problem type, ❷ problem/goal orientation, ❸ Easy to reconcile interests	

Type of mission	Details	Main content	Example
Accelerator Mission	A1	• Can be solved with S&T because of the nature of problem-oriented, simple mission structure, uncomplicated interests	Conquest of cancer
	A2	• Solution-oriented, interests are not complicated, but the mission structure is more complex than A1, so it can be solved through technological innovation as well as regulatory changes	Battery cell
Transformer Mission	T1	• Solution-oriented, there are many implementers and stakeholders, but it does not directly affect the end user, so goal achievement and management are easier than T2	Circular economy
	T2	• Problem-oriented, interactions between implementers due to direct contact with end users, complicated conflicts of interest	Quality of life

Mission setting	Mission investment	Mission management	Mission assessment
• Informed mission setting, such as collecting opinions from stakeholders and gathering knowledge about the nature of challenges • Traditional MOIP was a government-controlled structure, but recently, a distributed decision structure has been developed to solve difficult and complex problems • Measurable, time-bound objectives, subdivided goals to assess progress on missions, etc.	• Funding for the mission requires high risk tolerance and patience, and is provided from various entities including public and private sources • An eye for managing which parts of the innovation chain cause inefficiency in specific areas is also important for mission-oriented public investment	• The key is balancing centralized decisions on mission objectives and priorities with the need for decentralized public and private sector initiatives • Specifically, the need for new forms of collaboration, policy level, policy coordination capability, and legal means for continuous learning and adaptation	• A broader understanding of the outcomes generated by public policies, away from traditional cost-effectiveness analyses • The need to evaluate the portfolio rather than individual projects, and the evaluation should continue for continuous learning and adaptation

Principles	Task goals	Main characteristics
Strategic direction	Strengthening legitimacy for selection of specific challenging issues in the society, clear goal direction, and focused policy intervention	• (Legitimacy) Discovering agreement among various stakeholders (including the public) on the necessity and suitability of the mission • (Direction) Policy guides in a clear and well-known direction; strategic guidance is formed within the mission • (Intent) A specific and clear demand-based goal from the mission with clear timelines and milestones • (Flexibility) Goals and means of intervention to meet objectives are modified at the process stage if necessary
Policy coordination	Coordinating strategies and activities of other agencies included in the policy	• (Horizontality) Coordinating plans and activities of policy organizations dealing with different policy areas • (Verticality) Coordinating plans and activities of policy organizations at different levels of government to achieve missions • (Intensity) Decisions on interventions (targets, resource levels) are made collectively by the affiliated policy organizations • (Novelty) Including various alternatives such as plans and activities of other policy organizations and stakeholders, experiment coordination
Policy implementation	Ensuring continuity and effectiveness of intervention type and public-private partner resources	• (Policy mix consistency) Policy includes a consistent set of policy interventions (technical, financial, regulatory, etc.) tools beyond innovation cycles to support other fields, sectors, and markets • (Funding possibilities) Move to inject resources from the public-private stakeholders included in the initiative • (Assessment possibilities) To learn from the implementation of a continuous development perspective and evaluate results, give assessment procedures that adjust investment and performance indicators to the characteristics of the system from the start • (Flexibility) Use assessment and monitoring results to inform decision-making and revision of initiatives (revision of objectives, application of governance and operating procedures, etc.)

[9] The National Institutes of Health (NIH) is an organization dedicated to medical and health-related R&D and management

[10] SIP (Cross-ministerial Strategic Innovation Promotion Program): Science and technology strategic innovation program (5 years)

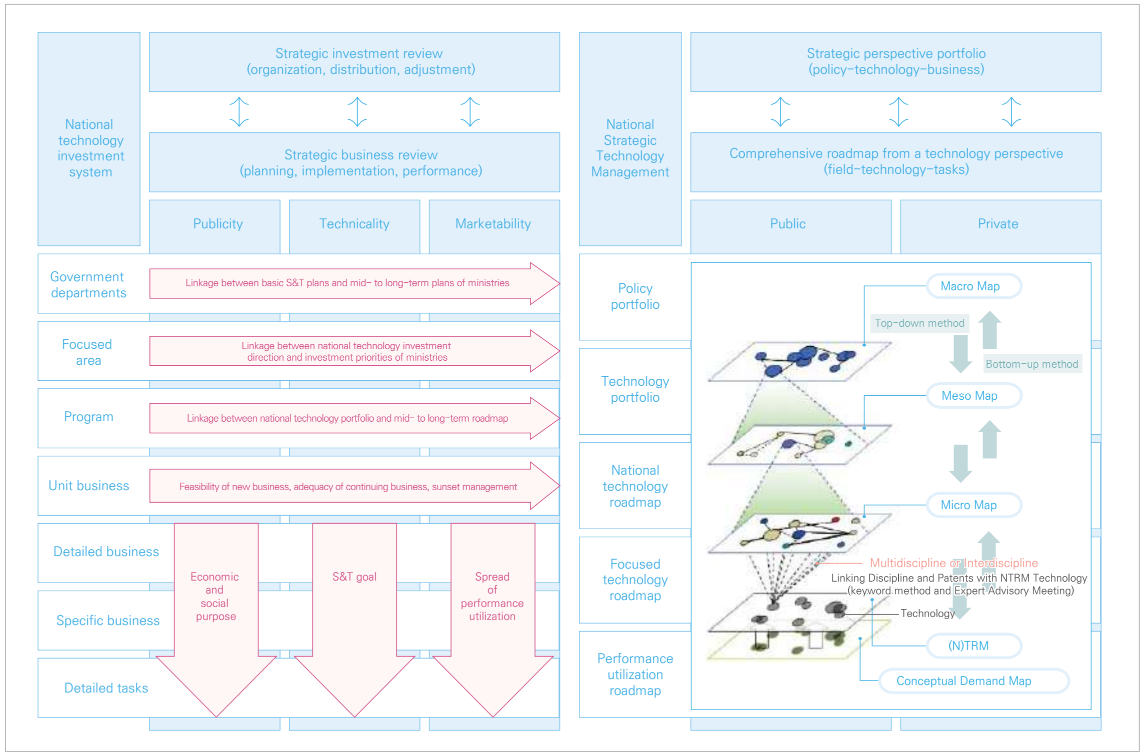
[11] PRISM (Public Private R&D Investment Strategic Expansion Program): Focused investment on new technologies for growth engines

[12] ImPACT (Impulsing PAradigm Change through disruptive Technologies): Innovation challenging project

[13] MOONSHOT (Moon Shot): A name that metaphorically expresses the challenge of lunar exploration, aiming for bold and disruptive innovation from a macro perspective

[14] ① Rodrik, Dani, The Return of Industrial Policy, Project Syndicate, April 12, 2010., ② OECD, Terms of reference of the project on the design and implementation of mission-oriented policies to address societal challenges, DSTI/STP(2019)8, 11 March, 2019

Figure 7 Concept of government R&D strategic investment system and structure of national strategic technology management



4. Strategization and systematization of leading R&D investment that turns crisis into opportunity

Korea has grown into a major S&T country that ranks 5th in the world in terms of national R&D investment and world innovation index, aiming to become a leading country. Challenging innovation investment and strategic R&D programs are essential to achieve those goals. Failure in challenging research should be reasonably judged, and key elements of success should be secured as achievements in the business and research process. In addition, the scope and system of cooperation and coordination between policy areas, and the planning, management, and evaluation system of problem-solving and mission-oriented projects should be specified according to the environment. To this end, it is necessary to design an economic and social understanding and blueprint for the necessity of challenging and innovative R&D investment. It is also necessary to structure the perception of innovation entities of industry-academia-research institutes and the pan-ministerial cooperation system on the urgency of creating a leading R&D ecosystem. In addition, it is necessary to consider the transition of existing micro-R&D goals and output-oriented management systems to mission processes and success-oriented strategies for macroscopic innovation challenges and problem-solving. For macroscopic innovation investment and strategic R&D systematization, first, mission-oriented programs with social challenges should be strengthened. It is essential to challenge innovation for transcendent social and economic issues such as responding to climate change, competition for technological supremacy, and overcoming low growth; expand cooperating programs with ministries and agencies; strengthen mission-oriented, top-down programs and business reorganization according to investment policy changes. Second, strengthening linkages between macroscopic mid- and long-term investment strategies and budgets should be prioritized. It is necessary to strengthen budget review for a portfolio-oriented program, support for the connection of mid- to long-term R&D business plans (basic plan-investment strategy), and investment management of the life-cycle of basics, application, and commercialization of national strategic technologies. Third, the focus should be placed on discovering new growth engines centered on the technology economy (digital and green). Priority should be given to the expansion of the digital economy, such as virtual world and virtual asset trading; the strengthening of investment in transformational technologies to preoccupy the convergence market; the development of basic foundations and human resources amid the rise of the green economy such as bio, energy, and environmental technologies; and the enhancement of innovation competitiveness. Fourth, it is important to streamline the government's R&D investment system of autonomy and responsibility. It is time to strengthen and continue the review system centered on large R&D, new projects, and strategic programs, review the self-organization of the sunset project budget, and redesign the program project and project budget system for national technology strategy management and investment portfolio operation. Fifth, it is vital to strengthen innovative investment (technology, region, university, company, and human resources) from an ecosystem perspective. It is necessary to expand mission-oriented program planning, budget review standards, and consulting to drive balanced performance in strategic investment. Sixth, data and evidence-based R&D investment, cooperation system, and scientificization should be promoted. It is necessary to introduce R&D investment data survey and analysis system based on a fund flow and accounting and establish a digital R&D budget system while invigorating an evidence-based R&D investment strategy community shared by ministries, specialized institutions, research institutes, universities, researchers, and the people. Leading countries in S&T should secure strategic investment capabilities and maturity of the R&D system. The priority condition required for leading countries is their leadership capabilities. As for a leading country capable of turning crises into opportunities, it is essential to have S&T philosophy and capabilities of challenge and innovation, strategic R&D systems, and research environments. Achieving the mission of realizing S&T based-advanced countries requires innovation policy of a leading philosophy, strategization and systematization of R&D projects, holistic understanding and cooperation of the government, industry, academia, and research institutes, and researchers' efforts and commitment, along with the vision from a resource-poor country to a knowledge-rich country. Systems that solve large and difficult problems secure high value and status. It is time to focus on exploring a leading R&D investment system, preparing strategic business management plans to create an innovative ecosystem, and challenging research environment to solve challenges and overcome limitations. Currently, the new government's S&T policy and R&D investment direction are being discussed at the next government's presidential transition committee. The government's R&D investment direction and standard plan will be supplemented in accordance with the state philosophy and detailed implementation tasks in the S&T field. Based on this, the government's R&D project budget in 2023 will be reviewed and finalized at the National Assembly.

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10 Emerging Technologies to Contribute to 2030 NDC(Nationally Determined Contribution)

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1. Research Backgrounds

Competition over technological hegemony intensifies around the world as the transition to a digital society is in full swing. To continue and lead growth amid these changing circumstances, securing independent emerging technologies that predict future social changes preemptively is necessary. In addition, it is crucial to present important issues in our society and the future direction of S&T by selecting emerging technologies.

KISTEP has been selecting the top 10 emerging technologies every year since 2009. The study on the selection of emerging technologies is meaningful in that it selects and presents our emerging technologies at the stage of moving away from a technology follower to a technology leader. KISTEP's 10 emerging technologies have the highest recognition and usefulness among the emerging technologies announced by major domestic institutions and are harnessed to prepare for the future society and establish S&T strategies by selecting emerging technologies[1].

[1] Emerging technology information is mainly used to "discover ideas for new R&D projects and tasks planning". To this end, content for technology planning, such as definition and explanation of emerging technologies, related socio-economic issues, technology trends, detailed step-by-step technologies, and challenges, are presented (Lim Hyun et al., 2019)

Notably, as the energy transition to carbon neutrality accelerates, emerging technologies are expected to bring major changes to Korean society in the next 5 to 10 years. To overcome the climate crisis, the international community has declared carbon neutrality goals and strengthened carbon regulations. There have been continuous discussions about the method and speed of reaching zero greenhouse gas emissions. This paper will examine ten emerging technologies contributing to achieving "the 2030 NDC" and discuss their implications.

2. Research Process and Details

"Carbon-neutral era" was chosen as the topic of KISTEP's future issues. Ten emerging technologies were finally selected by identifying future issues, nominating technology candidates, selecting emerging technologies, and conducting an in-depth analysis of the chosen technologies.

Table 1 Research Process of 2022 KISTEP Emerging Technologies

	Details	Method
(1) Identifying future issues	Identifying future issue candidates	· Establishing future issue-related DB centering on future foresight report ※The 6th S&T foresight survey, Future Strategy 2045, NIC Global Trends 2040, WEF Global Issue, etc.
	↓	
	Priority assessment on future issues	· Priority assessment for technical level assessment experts, KSTEP policy customers, and future foresight experts
	↓	
(2) Discovering emerging technology candidates	Discovering emerging technology candidates that can meet future demand Discovering emerging technology candidates ↓	· Setting the scope as technologies that can contribute to achieving the NDC goal by 2030 · Discovering technology candidates based on the start of social dissemination (~2030) by referring to the technology classification system of the Key Technology for Carbon Neutrality (draft) (2021.8.) · Coordinating technology candidates through written assessment by technical experts in each field and assessing their conformity with future issues
(3) Nominating emerging technologies	Nominating emerging technologies ↓	· Nominating the final 10 emerging technologies through expert consultation and discussion with internal researchers
(4) In-dept analysis of emerging technologies	In-depth analysis by technology	· Technology overview, domestic and foreign trends, prospects for 2030, relationships with other emerging technologies, etc.

3. Results

1) Identifying future issues

Literature studies were conducted to identify topics, or core trends, of KISTEP's future issues in 2022. First, by collecting and analyzing the trends and issues of the recently-released domestic and foreign prospect reports, S&T foresight research report, and the future strategy 2045, future social trends were derived from the perspectives of politics, economy, society, environment, and technology. Five trends likely to emerge as significant issues within the next 10 years and highly related to recent major social issues were selected as candidate topics (Table 4). In addition, trends that have been selected as KISTEP's 10 emerging technologies are excluded as much as possible to secure differentiation from existing research. A preference survey was conducted on KISTEP policy customers and future foresight experts who have a high understanding of the overall flow of S&T and policy trends, and additional topics were discovered.

Table 2 Topics of KISTEP Emerging Technology Candidates in 2022

Candidate topics	Description
10 emerging technologies to prepare for mega-urbanization	• Anticipating issues that may arise from urban overcrowding, absorption of surrounding areas, and acceleration of local hollowing, and discovering technologies to respond to them • Related issues (examples): - Economic revitalization of the Metropolitan Area (mega-cities) - A gap in infrastructure, such as cultural life - Acceleration of slumming in depopulated areas
10 emerging technologies to prepare for aging society	• Anticipating issues that may arise with intensified population aging resulting from a slowdown in population growth and the world's lowest fertility rate and discovering technologies that can respond to them • Related issues (examples): - Supporting the anti-aging and disease prevention industry - Development and industrialization of regenerative medical technology - Automation in the 3D industries
10 emerging technologies to prepare for the age of space life	• Forecasting the formation of a huge industry for realizing the space life and potential issues and discovering technologies that can respond to them • Related issues (examples): - Establishing payload launch and operation system - Expanding the concept of national security - Space business led by the private sector
10 emerging technologies to prepare for carbon-neutral era	• Anticipating issues under the carbon-neutral plan to zero carbon emissions in response to the climate crisis and discovering technologies to prepare for them • Related issues (examples): - Independence of new and renewable energy technologies - Recycling plastics and waste - Developing sustainable future energy sources
10 emerging technologies to prepare for platform economy	• Anticipating various issues arising from economic and social activities promoted by the platform and discovering technologies to respond to them • Related issues (examples): - Establishing a multi-product, small-batch economic system - Providing services without time/space constraints - Industrial leadership and control by a small number of companies

A survey was conducted on technology-level assessment experts and KISTEP policy customers on candidate topics for future issues. Based on the survey results, the "carbon-neutral era" was selected as a topic for emerging technologies in 2022.

Table 3 Survey Results on Topics of KISTEP Emerging Technology Candidates in 2022

Assessment index	Candidate topics				
	Mega-urbanization	Aging society	Space industry era	Carbon-neutrality era	Platform economy
Novelty	4.08	4.45	4.98	5.09	5.01
Interest·timeliness	5.06	5.82	4.57	5.95	5.29
Ripple effect	5.00	5.70	4.83	5.97	5.52
Technology relevance	4.29	5.52	6.33	6.09	5.19
Results usability	4.67	5.59	4.87	5.88	5.42
Total	4.62	5.42	5.12	5.80	5.29

Score by assessment index: 1 (very low) - 4 (moderate) - 7 (very high)

2) Deriving emerging technology candidates

A carbon-neutral plan to zero carbon emissions in response to the climate crisis has become a global trend. The adoption of the "Kyoto Protocol" the "Paris Agreement" to recognize and solve the seriousness of climate change has become a global agenda, forming a new international order. Korea has also joined the global trend to change its industrial and energy structure through the "2050 Carbon Net Zero Declaration" (2020.10.). Emerging technologies target issues that can bring significant change to Korean society in 5 to 10 years, and thus technologies that can contribute to achieving the 2030 NDC goal[2] are selected. The candidate group was discovered based on the start of social dissemination (~2030) by referring to the technology classification system of the "Carbon neutral major technology (draft)" announced in August 2021, and 13 emerging technologies were derived through written assessment by experts. Among 257 technologies obtained from the written assessment of experts, 13 technologies with great conformity and ripple effect were selected through internal expert discussions.

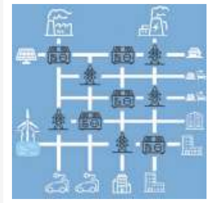
3) Nominating 10 Emerging Technologies

KISTEP's 10 emerging technologies were selected by comprehensively considering expert discussions for each emerging technology and assessment index scores. After reviewing the 17 critical areas of carbon-neutral R&D and the roadmap to revitalize the hydrogen

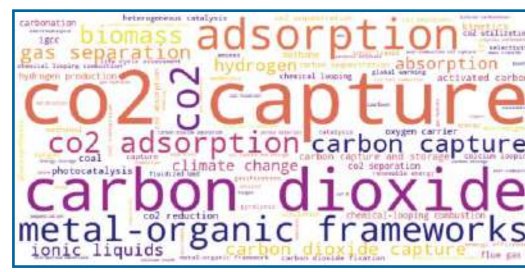
[2] 40% reduction in greenhouse gas emissions compared to 2018

economy, ammonia power generation technology aimed at commercialization by 2030 was added; the scope and outline of technology were integrated and adjusted; orientation was included in the name of technologies.

Table 4 10 Emerging Technologies to Contribute to 2030 NDC Goal

	Sector	Name of emerging technologies	Technology overview
	CCUS	CO_2 capture and conversion technology	Technology that captures CO_2 from gases emitted from industrial processes and converts them into fuels and basic chemical products
	Industry	Bio-based raw material and product production technology	Technology to reduce GHG emissions by converting petroleum base/applied raw material/plastic into biomass-derived base/applied raw material/plastic industry
	Industry	Carbon-reducing blast furnace-converter process technology	A technology to reduce the amount of carbon required for reduction in a blast furnace and a technology to reduce CO_2 Emissions by reducing the use of raw materials (molten iron) by expanding the use of scrap in the converter
	Transportation	High-capacity, long-life secondary battery technology	Secondary battery technologies including lithium-ion batteries used in electric vehicles and ESS, secondary battery management, and secondary battery technologies including modules/packs/systems
	Energy	Clean hydrogen production technology	Hydrogen production with technology to capture CO_2 from natural gas, naphtha, and LPG, or water electrolysis hydrogen production technology using renewable power or existing power source
	Energy	Ammonia power generation technology	Carbon-free power generation using clean fuels (hydrogen, ammonia) and ammonia step-by-step expansion conversion technology
	Energy	Power grid linkage system	Resolving power system instability due to renewable energy volatility and increase in EV charging infrastructure, securing power quality, improving distributed energy conversion efficiency, and upgrading system linkage standards
	Energy	High-efficiency solar cell technology	Next-generation solar cells such as perovskite, tandem, and heterojunction solar cells to overcome marginal efficiency
	Energy	Super large offshore wind power systems	Technology to install and operate offshore wind power system on a super large scale
	Environment	Useful resources (rare earth) recovery technology	Technology to collect, separate, sort and recover for rare earth recovery

4) In-depth Analysis of 10 Emerging Technologies



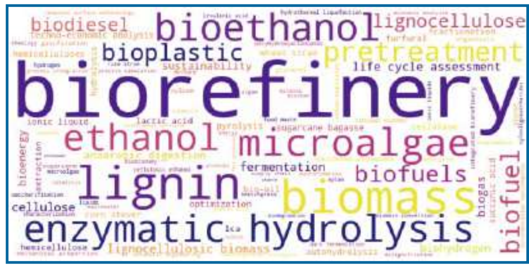
CO_2 capture and conversion technology 01

(Definition) A technology that captures CO_2 emitted from energy and industrial processes and converts the captured CO_2 into useful materials

(Necessity) To complete transition from fossil fuel-based energy to low-carbon renewable energy takes considerable time and resources, so to achieve carbon neutrality, it is necessary to develop technologies that curb carbon emissions by capturing, storing, and utilizing generated CO_2.

(Domestic and foreign trends) There are 65 CCS facilities worldwide, including large-scale capture; 26 are in operation, three are under construction, and 21 are actively developing technologies.

(2030 prospects) Expect a reduction effect that minimizes impact on existing industries through investment in eco-friendly infrastructure, the introduction of CO_2 capture and conversion technology accompanied by eco-friendly job creation, and improvement of completeness.



Bio-based raw material and product production technology 02

(Definition) Production of basic chemical materials based on a bio-refinery platform derived from sustainable plants or woody biomass replacing fossil materials (naphtha), demonstration material technology, and production technology of biochemistry, bioplastic synthesis, polymerization, and manufacture.

(Necessity) To reduce carbon emissions, it is necessary to convert naphtha and olefin, which are basic raw materials in the petrochemical field, into low-carbon and eco-friendly bio-materials, and efforts to link upstream (pyrolysis) and downstream (base oil production) are needed.

(Domestic and foreign trends) In Korea, technology is being secured mainly by large companies, and multinational chemical companies are actively pursuing a business transition to biochemistry.

(2030 prospects) The petrochemical industry is Korea's flagship export industry and is expected to transform into athe biochemical industry based on decarbonized and eco-friendly biomass to achieve the national greenhouse gas reduction goal and secure future technological competitiveness.

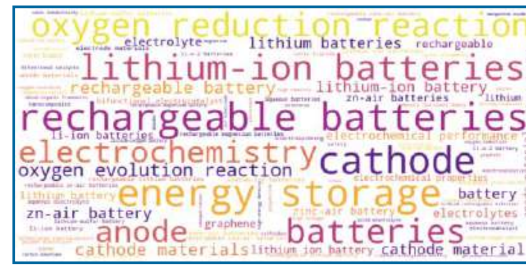
Carbon-reducing blast furnace-converter process technology 03

(Definition) Process technology to replace the fuel and raw materials used in the existing furnace-converter process and to link CCUS technology.

(Necessity) Since the efficiency of the domestic blast furnace-converter process is the world's highest and the process carbon usage is close to the theoretical minimum required for iron production, it is essential to replace carbon-based materials and fuels in the existing furnace-converter process and develop carbon emission reduction technology through oxygen blast furnace technology for CCUS technology.

(Domestic and foreign trends) Commercialization technology is being developed in Korea, and policy efforts for technology demonstration are continuing overseas.

(2030 prospects) Carbon-reducing blast furnace-converter process technology is expected to contribute to carbon reduction through commercialization after technology development by 2030.



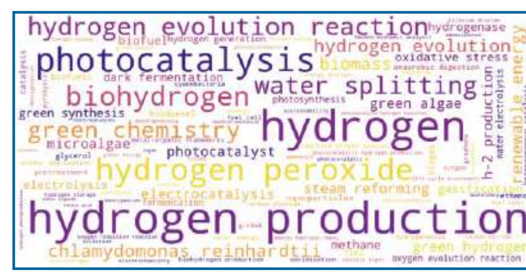
High-capacity, long-life secondary battery technology 04

(Definition) A device that can convert external electrical energy into chemical energy, store and convert it back to electrical energy when needed, and perform such conversion repeatedly.

(Necessity) Demand for each purpose is increasing due to the expansion of secondary battery applications such as electric vehicles and new and renewable energy storage, but lithium-ion secondary batteries are reaching theoretical performance limits, requiring the development of next-generation secondary batteries.

(Domestic and foreign trends) Policy and financial support are accelerating worldwide.

(2030 prospects) Secondary batteries are expected to play a key role as new and renewable energy, ESS, and eco-friendly vehicles expand.



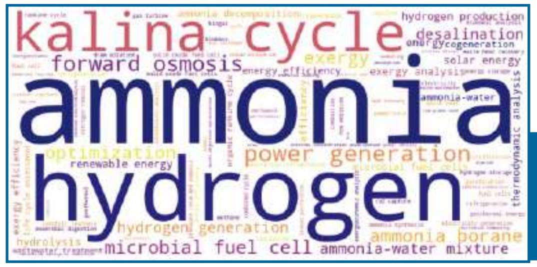
Clean hydrogen production technology 05

(Definition) A technology that produces hydrogen in a way that does not emit or emits significantly less CO_2 in the process of manufacturing hydrogen.

(Necessity) Hydrogen is attracting attention as a new carbon-reducing method in the energy-consuming industries (steel, petrochemical, cement, aluminum, etc.) in Korea's carbon-neutral path, and it can be used in the lifecycle of energy production, transportation, and consumption to create new industries and re-start existing industries.

(Domestic and foreign trends) In the case of green hydrogen production, a demonstration project is in progress, but there is a technology gap between domestic (hundreds of kW) and overseas (MW) in terms of scale.

(2030 prospects) New infrastructure investment and conversion costs are expected to increase due to the transition following carbon neutrality and energy conversion, and social acceptability issues will be raised.



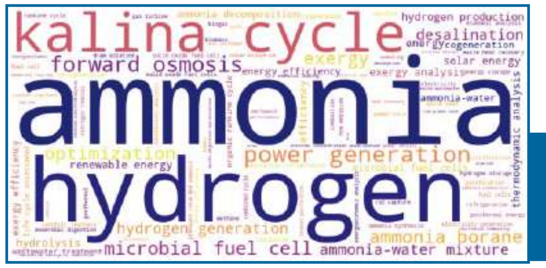
Ammonia power generation technology 06

(Definition) A technology that converts LNG/coal, the existing fuel for thermal power generation gas turbines/boilers, into ammonia fuel that is carbon-free and innovatively reduces CO_2 and fine dust emissions as well as equivalent performance to existing gas turbines/boilers.

(Necessity) Ammonia (NH_3) containing hydrogen can be stored and transported at a low cost at room temperature. The effect of reducing CO_2 emissions can be maximized while minimizing facility investment and changes in coal-fired power plants during the conversion process to renewable energy. Therefore, short-term localization technology development is urgently needed (NH_3).

(Domestic and foreign trends) Basic research is being conducted in Korea through the operation of a hydrogen/ammonia power generation demonstration promotion group, etc., and overseas, gas turbine demonstration research is being conducted.

(2030 prospects) As the use of ammonia, a carbon-free fuel, is very important for the decarbonization of thermal power generation, demand for ammonia is expected to accelerate in Korea, Japan, Southeast Asia, and China, where the proportion of coal-fired power generation is high.



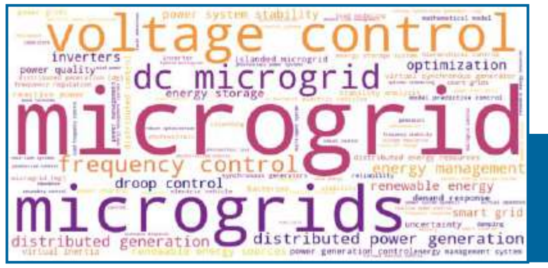
Power grid linkage system 07

(Definition) Grid-connected system technology essential for stabilizing power systems and securing power quality including energy storage systems (e.g., renewable energy and charging infrastructure for electric vehicles).

(Necessity) It is urgent to resolve the imbalance of power supply and demand due to regional differences in renewable energy generation sources, change the characteristics of the power system, and change the infrastructure and operating system under changes in power composition.

(Domestic and foreign trends) Korea is responding to the expected lack of systematic inertia, and standard advancement and demonstration are ongoing overseas.

(2030 prospects) The transition from a power supply system centered on large-capacity long-distance transmission to a power supply system that consumes locally produced electricity in the same area and connects the minimum amount of electricity with nearby areas.



High-efficiency solar cell technology 08

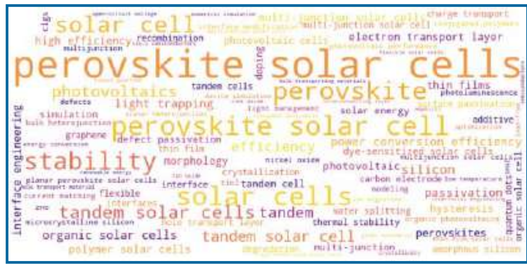
(Definition) Super high-efficient solar cell technology.

(Necessity) Global installation volume continues to grow every year, but LCOE needs to it is necessary to improve output and reduce manufacturing costs through innovative technology development differentiated from previous ones to improve LCOE[3].

(Domestic and foreign trends) Korea is breaking the world's highest efficiency record for next-generation solar cells (perovskite), and Germany has reported the world's highest efficiency as perovskite/crystalline silicon-based tandem solar cells.

(2030 prospects) Due to the policy will for carbon neutrality and the decrease in the technical cost of new and renewable energy, the use of fossil fuels will be substantially reduced, and the proportion of new and renewable energy, especially solar and wind power, will increase significantly.

[3] Levelized cost of electricity



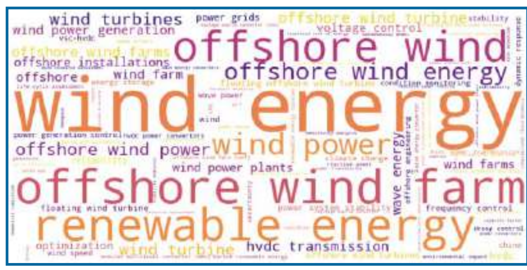
Super large offshore wind power system **09**

(Definition) A technology to install and operate offshore wind power systems on a large scale

(Necessity) The primary energy sources for new and renewable energy supply are solar and wind power. Offshore wind power is a technology-intensive national infrastructure business that is rapidly growing as an energy source that can be produced domestically rather than imported from abroad.

(Domestic and foreign trends) Denmark, the US, Germany, etc., are leading the way, and some domestic parts companies have been recognized for their technological prowess, but their systems are lagging behind those of advanced overseas companies.

(2030 prospects) Due to the nature of super-large offshore wind power, which is difficult to maintain, the LCOE of highly reliable products is expected to improve more than cost-effective products.



Useful resources (rare earth) recovery technology **10**

(Definition) A technology to recover and recycle rare earth, which are materials with the highest national strategic and industrial importance among rare metals from waste resources.

(Necessity) In accordance with global eco-friendly policies, the demand for rare earth elements such as neodymium, which is required for permanent magnets used in wind power generation and electric vehicles, is increasing due to the increase in demand for new and renewable energy.

(Domestic and foreign trends) Research is underway to diversify supply chains, reduce rare earth use, and develop alternatives to cope with China's resource weaponization.

(2030 prospects) Unlike existing production systems limited to some countries, resource recovery technology development through high-efficiency rare earth recovery and recycling from urban mines that generate waste resources.

4. Conclusion and Implications

Ten emerging technologies were discovered with the theme of the carbon-neutral era, and in-depth analysis was conducted considering novelty, interest and timeliness, impacts, technology relevance, and outcome utilization. Technologies that can contribute to achieving the 2030 NDC goal were set as candidates. The candidate group was discovered based on the start of social dissemination (until 2030) by referring to the technology classification system of the carbon-neutral core technology (draft) announced in August 2021. KISTEP's 10 emerging technologies were selected by comprehensively considering expert discussions for each emerging technology and assessment index scores. Each emerging technology shows a complementary relationship with other technologies, which is expected to create positive synergy effects to contribute to the 2030 NDC goal.

It is necessary to improve laws and regulations and secure infrastructure to promote the commercialization and development of emerging technologies. First, it is required to prepare incentives to attract various private investments in laws and systems while preparing institutional foundations and support measures for efficient technology development and industrial development. In addition, it is necessary to secure related infrastructures, such as establishing a foundation for standardization and certification and providing test beds by operating a representative demonstration center for each industry or a comprehensive demonstration center at the national level. Since the supply of professional human resources to narrow the technology gap with advanced countries is insufficient, measures, such as human resources development programs that can supply and demand skilled human resources should be sought throughout the industry. Also, various research methodologies, such as domestic and foreign emerging technologies and expert opinions were applied based on carbon-neutral core technologies (draft) to select ten emerging technologies that will contribute to the 2030 NDC goal, but improvement is needed for the following fields.

First, there is a limit to quantitatively assessing the contribution to the 2030 NDC goal because items, such as economic impacts, growth stage, and market entry level for each emerging technology are not included. Second, since the selection and in-depth analysis of emerging technologies are carried out every year, it is necessary to consider the method of providing consistent information, including the same detailed items. Through these improvements, it is expected that KISTEP's 10 emerging technologies will contribute to the 2030 NDC goal and be more effectively used to present the future direction of S&T.

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KISTP Think 2022, 15 S&T Innovation Policy Agendas[1]

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1. Background

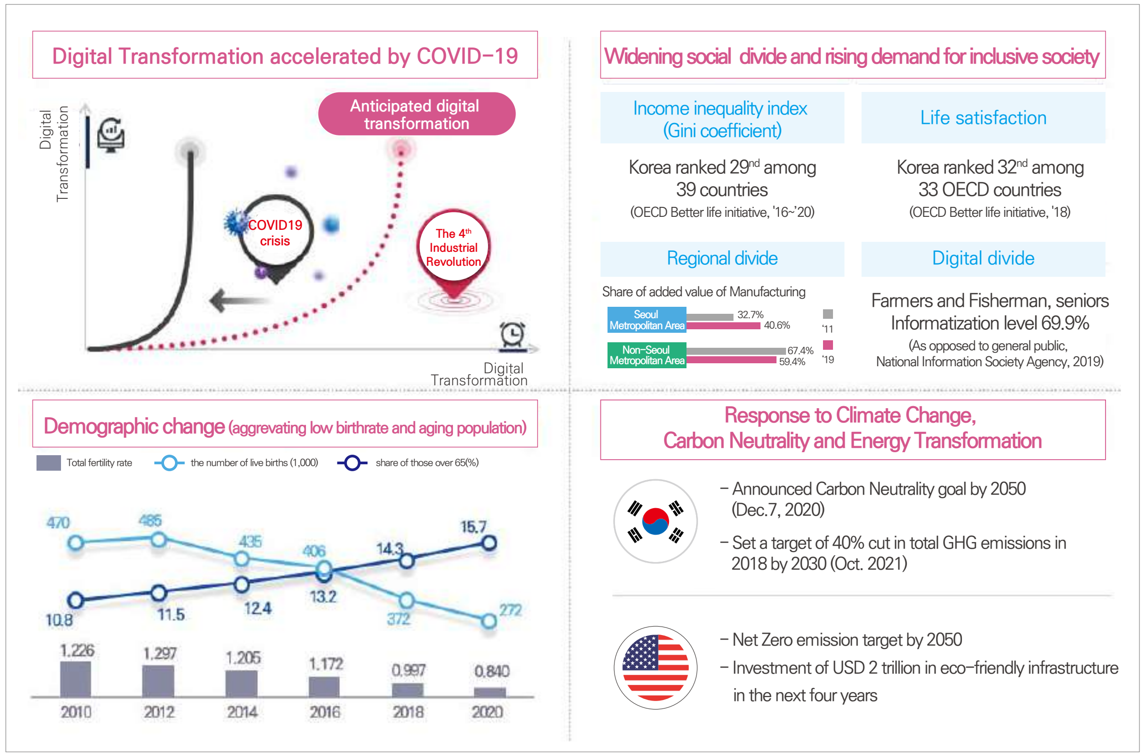
As uncertainties surrounding the future heighten with a prolonged COVID-19 pandemic, it demands that we discover and execute policy agendas to join the ranks of the globally advanced countries by overcoming a new normal (New Normal 2.0) with science and technology. In particular, 2022 marks the beginning of the Post-COVID-19 era. It is high time for us to discover and envision agendas for S&T innovation and R&D policy for sustainable national growth in the future. It is also a time to go beyond the problems in S&T fields, diagnose economic, industrial, societal, and cultural phenomena, and contemplate the role of S&T in the future. With heightened uncertainties stemming from a change in the global environment, Korea is going through a demographic shift with a low birthrate and aging population and facing various risks, including a widening social and regional gap.

In addition, the combined national R&D investment of the public and the private is projected to reach KRW 100 trillion in 2022. According to the national financial execution plan, the government R&D budget is expected to exceed KRW 30 trillion in 2023. In the era of KRW 30 trillion in the government R&D budget, it is necessary to discover and execute policy agenda to enhance the national R&D results, such as establishing the public-private partnership.

This report is to examine potential policy agendas in advanced national S&T innovation system and national R&D performance, and suggest critical agendas for KISTEP Think 2022, taking into account a ripple effect and urgency.

[1] Kim, Hong-young, et al., "Study on the government R&D budget structure and measures to improve a budget allocation and adjustment system", Excerpted part of KISTEP's projects and reorganized

Figure 1 Major Characteristics of the Transformation Period



2. The latest innovative environmental changes analyzed using Big Data keyword analysis

1) Analysis Overview

Big Data was used to analyze and organize S&T innovation policy issues in diverse areas, such as the economy, society, and industry. In addition, data from the media, S&T policy, and trend analysis were selected to reflect diverse perspectives and data.

As for analysis procedures, big data was gathered, analyzed and visualized, and then interpreted to uncover a hidden meaning. As the first step of big data analysis, 1,045,726 materials were collected and cleaned. To analyze the collected materials, how often specific words were mentioned and appeared in the same sentence concurrently was measured and used to build network data based on the analysis. VOSviewer and Python were utilized for data visualization to help understand the relationship between keywords intuitively. The data were expressed in Word Clouds, Inter-Topic Distance Map, and Network Map.

Figure 2 Process of Big Data Keyword Analysis

Data Collection	Data Analysis	Visualization	Meaning Derivation
Data Collection	Keyword Frequency	Word Clouds	Extract issues by field
Data cleaning/data pre-processing for analysis	Co-occurrence matrix	Topic Modeling	
		Semantic Network Analysis	

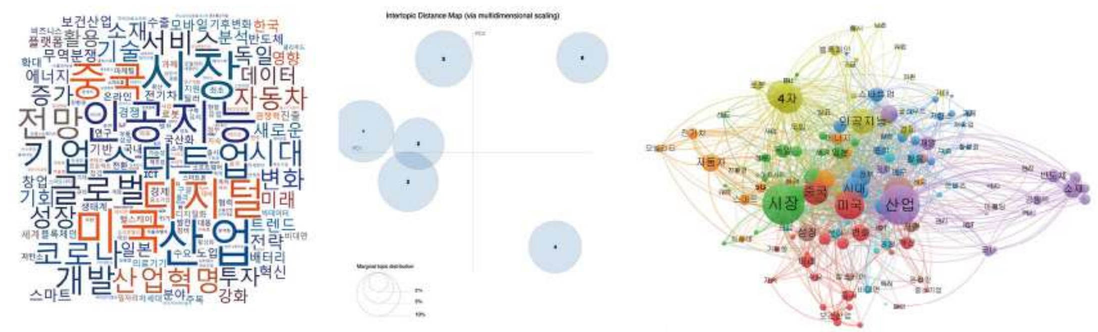
2) Major Analysis Results

Keyword Frequency Analysis was performed on data derived from the media, significant government policies, technologies, and industry trends from major institutes to find out main keywords first. Based on the analysis results, Topic Modeling and Semantic Network Map Analysis were used for a comprehensive review. Consequently, it was found that keywords for each dataset were very similar, serving as evidence that consensus was reached to a certain degree concerning global changes and diverse risk factors facing our society.

In addition, the results of big data-based keyword analysis were reviewed, and eight areas were identified consequently. Five major areas were selected for potential agendas, considering the meaning and significance of those eight areas.

Carbon neutrality and stronger competitiveness in material, component and equipment are required to boost the standing and influence of Korea in the international community through S&T more than any other policy. Combining these two areas, it proposes ① global scientific and technological leadership in the era of PPax Technica. Given that discussions on pending issues to realize public safety through new infectious diseases and climate crisis are urgent, it proposes ② a healthy and safe inclusive society for citizens. To actively respond to the fourth industrial revolution and digital transformation, and stress the importance of creation of new industries through these responses, it proposes ③ a leading innovative economy in the digital transformation era. To overcome the gravest threats of our future like a low birth rate and an aging population and lay the foundation for new growth, it proposes ④ a system innovation for educating and supporting S&T human resources in the era of demographic decline. Last but not least, it proposes ⑤ the advancement of innovation system in the era of KRW 100 trillion in the national R&D budget to reinforce our capabilities and efficiency of R&D, the very platform to implement all of the proposals mentioned above successfully.

Figure 3 Five Major Areas chosen through Big Data-based Keyword Analysis



WordClouds　Topic Modelling　Semantic Network Map

Big data-based keyword analysis
Carbon neutrality
Societal issues, Public safety
Digital New Deal
Materials, components and equipment, technology soverignty
New Convergence Industry
Nurturing human resources
Jobs
Other

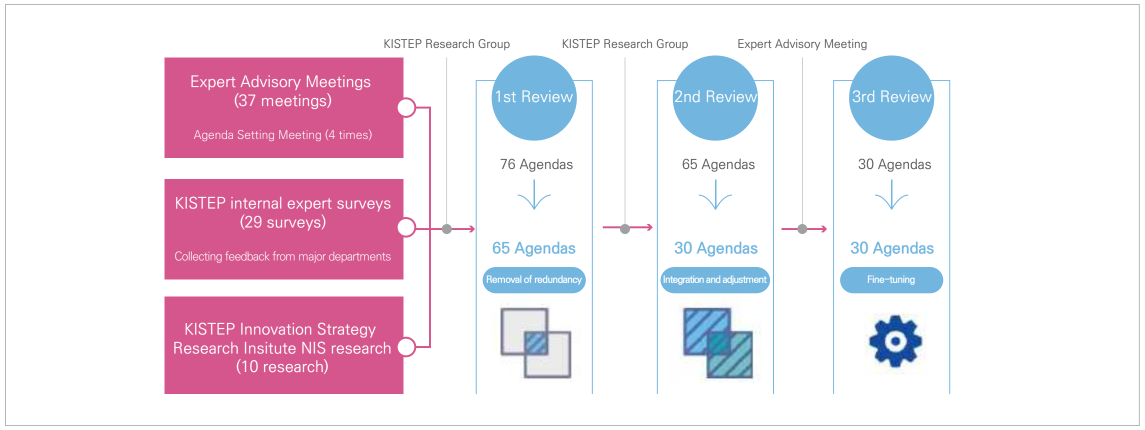
Key Five Areas	
1	Global Scientific and Technological Leadership in the Era of Pax Technica
2	A Healthy and Safe Inclusive Society for Citizens
3	A Leading Innovative Economy in the Digital Transformation Era
4	A System Innovation for Educating and Supporting S&T human resources in the Era of Demographic Decline
5	Advancement of Innovation System in the Era of KRW 100 trillion in the National R&D Budget

3. Key agenda selection process

1) Discovery of potential agenda

Based on the big data-based analysis, five major areas and corresponding issues were reviewed, and noteworthy agendas for 2022 have been identified, considering X-events that need close attention in the future.

Figure 4 Potential agendas Selection Process



Based on 76 agendas derived from expert advisory meetings, KISTEP internal expert surveys, NIS research results of the KISTEP Innovation Strategy Research Institute, three rounds of reviews and modifications were conducted to select 30 agendas for final candidates.

Table 1 30 potential agendas for S&T innovation policies

Candidate topics	Description
Global S&T leader in Pax Technica	(1) S&T sovereignty for survival in the era of technological supremacy
	(2) Innovation leader in carbon neutrality technology for conversion to low carbon society in the future
	(3) Expansion of adventurous R&D for global leadership, "S&T Loonshot" (TBD)
	(4) Strengthening a sustainable strategic alliance and cooperation system in S&T
	(5) Acquisition of next-generation materials, components and equipment, and value chain innovation
	(6) The national R&D strategy of circular resources for a vibrant circular economy
A healthy, safe and inclusive society	(1) Inclusive S&T innovations for resolution of social divide and inequality
	(2) Development of regional innovation capabilities to address inter-regional divide and replenish a growth potential
	(3) Innovating Mission-oriented R&D for resolution of societal challenges
	(4) Establishment of an intelligent system in preparation for future risks
	(5) A sustainable growth strategy in Bio health (vaccine and medicine) in the post-COVID-19 era
	(6) Promoting "Geron technology"(TBD) for a better quality of life for the seniors
An innovative economy leading Digital Era	(1) Building capabilities in the Top 3 digital technologies for the promotion of the AI revolution
	(2) Development of a new convergent industry through digital transformation
	(3) The sophistication of the ecosystem for the growth of innovative ventures for job creation
	(4) Forging a new public-private partnership for the development of future growth engine
	(5) Creation of a cooperative ecosystem for large companies and SMEs to promote digital transformation
	(6) Responding to adverse effects of digital transformation and strengthening social acceptance

Advancing innovative system for the national R&D	(1) Strengthening the role of the government and the public sector in leading demands for innovations of the private sector
	(2) Innovating the national R&D planning and management system in the era of 30 trillion in R&D budget
	(3) Active technology transfer and commercialization of the national R&D results
	(4) Strengthening data-based decision-making system for S&T innovation policy
	(5) Advancing the ecosystem for basic research considering characteristics by sector
	(6) Establishment of governance for a sustainable S&T innovation

2) Confirmation of 15 S&T innovation policy agendas

Based on survey results, KISTEP's 15 S&T innovation policy agendas are confirmed for 2022 by selecting three agendas in each of the five areas after a comprehensive deliberation processes through discussions and debates of the expert advisory board.

Figure 5 15 S&T innovation policy agendas

1 In the Pax Technica Era Attainment of global S&T leadership

- S&T sovereignty for survival in technological supremacy
- Technological innovation leader in carbon neutrality for conversion to a low-carbon society in the future
- Acquiring next-generation materials, components, and equipment and innovating the value chain

2 A healthy, safe and inclusive society

- Inclusive S&T innovation for addressing social and regional divides
- Mission-oriented R&D innovation for resolving societal challenges
- Continuous growth in the bio health field in the post-COVID19

3 An innovative economy leading the digital era

- Attaining competitiveness in the TOP 3 digital technologies that promote the AI revolution
- Growth of new convergent industry through digital transformation
- Advancing an ecosystem for the growth of innovative businesses for job creation

4 Innovating a system for nurturing and utilizing S&T talents in the population decline era

- Developing highly skilled talents strategically and inducing the influx of innovative international talents
- Expanding support for the growth of young S&T talents
- Strengthening capability for response to changing tasks and jobs and activating transition training (up&reskill)

5 Advancing the innovation system in KRW 100 trillion of the national R&D budget

- Strengthening the role of the government and the public sector that leads the private demand and support system
- Making the national R&D system and evaluation system autonomous and accountable in KRW 30 trillion in the R&D budget
- Activating technology transfer and technology commercialization of the national R&D results

4. Contents of 15 S&T innovation policy agendas

1) A global S&T leadership in the era of Pax Americana

1. S&T sovereignty for the national survival in the era of technological supremacy

● **A strategy is necessary to cope with global technological competition and nationalism against the backdrop of a changing global landscape and S&T innovation environment.**

<Task 1> Enactment of laws to nurture and support essential national strategic technologies and establishment of a management system
<Task 2> Establishment of "Custom National R&D strategy"by type of advanced strategic technology
<Task 3> Reinforcement of Korea-US technology alliance and cooperative system with major countries strategically

2. Technological Innovation leadership in carbon neutrality for conversion to a low-carbon society in the future

● **As competition heats up to control the global carbon market, Korea must devise a cooperation strategy for technological diplomacy and countermeasures.**

<Task 1> Enhancing execution capability of Strategy Roadmap for Technological Innovations of Carbon Neutrality (Jan. 2022)
<Task 2> Implementing ten flagship projects based on innovative technologies for carbon neutrality
<Task 3> System support for strengthening innovation capability of the private sector

3. Acquisition of technologies in next-generation materials-components-equipment fields and innovation of the value chain (Materials-Components-Equipment 3.0 strategy)

● **As manufacturing powers like the US, China, Japan, and Germany strengthen strategic competitiveness in new materials, components and equipment and restructure GVC, it is very critical for Korea to develop and implement preemptive measures thoroughly.**

<Task 1> Identifying and developing core strategic technologies in next-generation materials and components and implementing Flagship projects
<Task 2> Developing and implementing a "10-year plan for acquisition of technological competitiveness in advanced technology equipment".
<Task 3> Identifying support areas for the establishment of Connected Enterprise* for GVC/RVC Innovation → helping form an alliance and relevant strategies for the establishment of Connected Enterprise

2) A healthy, safe and inclusive society

4. Inclusive S&T innovation to address the social and regional divide

● **S&T needs to boost its traditional role of contributing to economic growth and seek inclusive growth by addressing various social and regional divides.**

<Task 1> Reinforcing the role of S&T in addressing social divides, such as digital, educational, and medical divide
<Task 2> Addressing inter-regional divides and advancing innovative regional capabilities for growth potential

5. Mission-oriented R&D innovation for tackling societal challenges

● **As the public expectations of S&T increase, so does the demand for resolving societal challenges. However, R&D outcomes have yet to be applied or spread enough. Thus, it is necessary to help the public experience the benefits of R&D outcomes.**

<Task 1> Implementing ten mission-oriented pan-government innovative policy initiatives, "K-Moonshot project" (TBD)
<Task 2> Establishing a government-funded research institute-leading R&D system to address societal challenges
<Task 3> Expanding investment in R&D for resolution of societal issues over the next five years by twofold from the current KRW 1.6 trillion

6. Sustainable growth of the bio-health sector in the post-COVID-19

● **Based on the understanding of the industrial characteristics of the bio health industry, establishing an industrial ecosystem for the public and the private can cooperate from R&D to Commercialization.**

<Task 1> Establishing an ecosystem to make the bio health industry a mainstream industry
<Task 2> Developing core technologies in response to infectious diseases and reinforcement of support for the national R&D
<Task 3> Data-based research and innovation of the bio health industry

3) An innovative economy leading the digital era

7. Attaining global competitiveness in the Top 3 digital technologies that spur the AI revolution

● **Boosting technological competitiveness in prep for conversion to the data-centric economic system for the advancement of corporate competitiveness and a sustainable industrial growth**

<Task 1> Expanding strategic R&D investment in core digital conversion technologies
<Task 2> Implementing next- generation D·N·A technology and creative and adventurous R&D program (Next D·N·A Extreme Challeng)
<Task 3> Becoming a center of the national AI research ecosystem and creating the national AI network

8. Developing a new convergent industry through digital transformation

● **Given the stagnant growth of the manufacturing sector and rising demand for "untact" services, it is urgently necessary to analyze sector-level issues and environmental changes for digital transformation across the industries and draft countermeasures.**

<Task 1> Strengthening manufacturing competitiveness through digital transformation
<Task 2> Strengthening a support system for the discovery and creation of new manufacturing-service convergent industry
<Task 3> Nurturing the growth of 'untact' industries, such as 'M Industry(metaverse-related industry)' (TBD), and strengthening system support

9. Advancing an ecosystem for the growth of innovative companies for job creation

● **While policies to spur the development and growth of innovative companies are actively implemented, most government and private investment policies still need to be increased. Thus, various policy attempts are required.**

<Task 1> Taking adventurous R&D projects depending on the growth level of startups and diversifying support mechanism
<Task 2> Supporting diverse VC investments in innovative companies

4) Innovating a system for the development and utilization of S&T talents in the era of population decline

10. Developing and tapping into high-level talents strategically and promoting the influx of innovative international talents

● **Before the rapid population decline around 2030, developing S&T talents is necessary to respond to changes in the future society accelerated by advanced S&T.**

<Task 1> Promoting university research institutes in a strategic field in need of the national support
<Task 2> Establishing a hub for global S&T talents based on a prestigious university research institute
<Task 3> Expanding support to induce international S&T talents to remain in the domestic labor market

11. Expanding support for the growth of young S&T talents

● **A lifecycle support policy is required to attract, nurture and utilize young S&T talents to ensure the influx of next-generation talents.**

<Task 1> Inducing the influx of intelligent young S&T talents
<Task 2> Strengthening treatment and rights of student researchers and expanding the post-doc research programs
<Task 3> Creating stable jobs for young S&T talents

12. Capacity building for evolving tasks and jobs and transition training (up & reskill)

● **As a significant number of jobs have disappeared in the traditional industries and new jobs have opened up in new digital technology industries, there is a rising demand for capability development of the existing workforce and life-long education.**

<Task 1> Development and expansion of diverse Continuing Education programs in response to changing tasks and jobs
<Task 2> Career development of female and highly skilled S&T talents
<Task 3> Establishment of an online platform to support individual career development and development of education technology and relevant industry

5) Advancing a system for innovations in the era of KRW 100 trillion national R&D budget

13. Reinforcing the role of the government and public sector in driving demand for private innovations and supportive system

● **Government R&D has supplied most technologies until recently. However, private demand-driven innovation policies were relatively insufficient in commercializing R&D results and entering into foreign markets.**

<Task 1> Expanding collective purchase of innovative products to create demands for private innovations and initial markets
<Task 2> A stronger taxation support to promote corporate R&D and innovation activities
<Task 3> Stimulating regulatory changes to accelerate the growth of new technology and new industry

14. Making autonomous and responsible R&D investments and innovating the national evaluation system in the era of KRW 30 trillion in R&D budget,

● **From a macro-and strategic perspective, the government's R&D investment and evaluation system must transition to an autonomous and accountable system in response to rapid environmental changes like the increasing size of R&D investment and diversification of the research ecosystem.**

<Task 1> Implementing 'a strategic R&D program' at a national level and provisioning separate funds
<Task 2> Innovating evaluation of the national R&D project based on Autonomy and Accountability
<Task 3> A stronger strategy for the government R&D investment and allocation and adjustment of budget

15. Activating technology transfer and technology commercialization developed under the national R&D projects

● **Technology commercialization performance from R&D projects has shown a steady increase, but the qualitative aspect of loyalty revenue per case has been stagnant. Thus, a countermeasure to vitalize the relevant system is required urgently.**

<Task 1> Implementing inter-ministerial national R&D TRL Booster Program'(TBD)
<Task 2> Pursuing 'Market-Up Project'(TBD) for more sophisticated technology transfer and commercial market
<Task 3> Reinforcing capability of Technology Licensing Office(TLO) for technology transfer and building SME's capacity for technology commercialization

5. Conclusion

As seen in the diverse policy agendas above and detailed projects, Science and technology are forecast to go beyond a means for economic and industrial development to become a key driver of changes and innovations in our society. In other words, Science and technology are being utilized as important means directly or indirectly to resolve many of our issues. Consequently, decisions that we make today will have a significant impact on the status of the future. Furthermore, the key to the US-China competition for hegemony will be cutting-edge technologies like semiconductors and network technology. Green hydrogen and carbon capture and storage technologies to materialize carbon neutrality are essential to respond to global climate change. Each country is engaged in fierce competition to develop space resources in the distant future, aiming to secure S&T capabilities.

Thus, if the science and technology policies for the future focus on a discussion over simply strengthening S&T competitiveness and technological capabilities, it would be meaningless. The policies must incorporate overall societal changes and interests in the planning and implementation phases. To that end, primary conditions to implement S&T policies on the ground must also be considered.

First, it is essential to strengthening leadership by revamping the administrative system overseeing and coordinating S&T innovation policies whose clout gets bigger in society. Currently, the status and function of the Science and Technology Innovation Division of the Ministry of Science and ICT, an oversight body of S&T innovations, must be expanded and reinforced. Also, changing the Presidential office's Science and Technology Advisory system to a chief secretary of Science and Technology Innovations must be considered.

Second, as a key to national competitiveness, the importance of S&T must be taken into account, and a stable financing structure must be prepared, recognizing investment in S&T as essential for the future. The investment in S&T is not just for advancing Science and knowledge but for preparing for future risks and crises. Unless there are special reasons, a specified portion of the total budget must be steadily earmarked for research and development.

Third, the current legal system must improve in a way that can incorporate changing environment that further expands interactions between S&T, society, and culture and prepare for the future. S&T policies must depart from the current R&D-centered approach to one that oversees the overall S&T-based innovation policies, including policies to address economic and societal issues and respond to future risks. Therefore, revising the Framework Act on Science and Technology to the Framework Act on Science and Technology Innovations is necessary.

The environment surrounding us is evolving rapidly, and the complexity is rising. Potential risks will also increase if we fail to prep for the future. To ease the shock stemming from changing circumstances and transition to an innovative system that turns a risk into an opportunity, it is critical to monitor emerging issues and constantly develop a strategy in response.

KISTEP plans to monitor and analyze domestic and global trends each year in a periodic and structured manner and highlight and propose issues worthy of our attention. Core agendas for Science and Technology Innovation Policies will be proposed and actively promoted through major media to build public consensus on issues regarding science and technology innovations.

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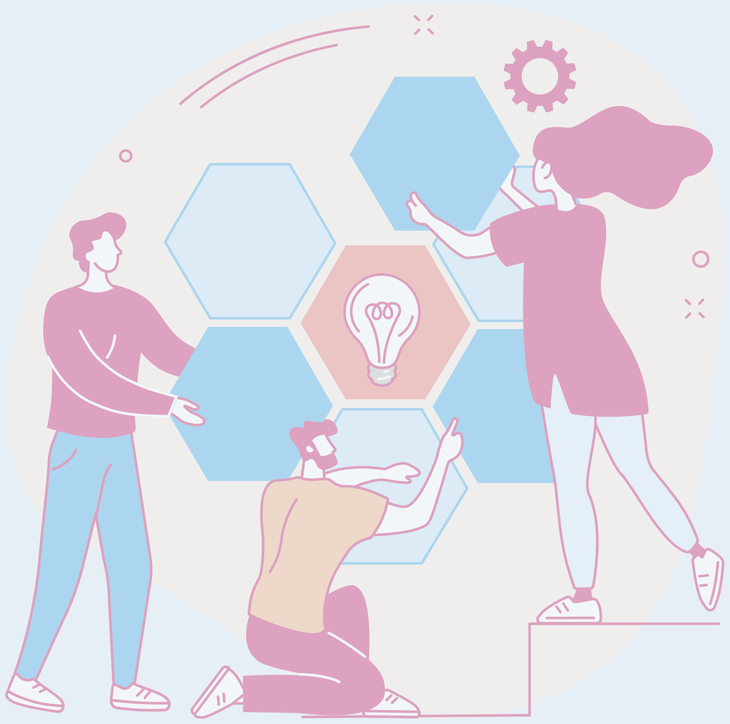

KISTEP R&D and Beyond 2022

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Definition of Digital Transformation Risk Issues and Response Strategies related to Digital Transformation: Focusing on Negative Effect of AI

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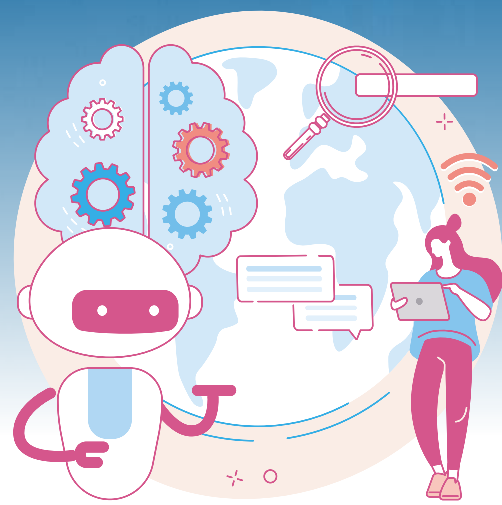


1. The Definition and Impacts of Digital Transformation

(Definition of digital transformation) This section will comprehensively define digital transformation through literature study as there is no agreed definition for digital transformation and its scope is also vague.

Table 1 Definition of Digital Transformation

Source	Definition
Jang Hoon (2017)	Digital transformation means a transition based on digital technologies and differentiated changes. In the industrial perspectives, it is defined as "creating new value by fundamentally changing corporate strategies or systems based on various digital technologies".
National Information Society Agency (2019)	Reorganizing industrial structure centering on business models based on digital technologies such as AI, Cloud, and Data
Kim Yong-jin (2018)	Digital transformation is the basis for object-to-object communication, real-time data accumulation and analysis, and product service and service commercialization
IBM (2011)	Integrating digital and physical elements to transform business models and set new directions for industries
Agile Elephant (2015)	A concept that includes digitalization of assets, changes in thinking and working process of organizations, creation of leadership and new business models, and use of technologies for improving experience of stakeholders, customers, and employees
IDC (2015)	A continuous process where companies adapt to disruptive changes in customers and markets (external ecosystem) by harnessing digital capabilities to create new business models, products and services, or where they push for this
A. T. Kearney (2016)	Corporate activities that companies dramatically enhance competitiveness of current business by preemptively coping with changes in the business environment driven by digital new technologies (ICBM (IoT, cloud, big data, mobile)+AI) or that they seek new growth through new business

Table 2 Impacts of Digital Transformation

Source	Impacts	Details
Jang Hoon (2017)	Reorganization of business structure	Digital transformation reorganizes overall business system by incorporating ICT to the value chain of existing business (e.g., Starbuck's new digital venture department, and digitalization of manufacturing process of traditional manufacturers such as GE and Adidas)
Lim Hee-jong et al. (2021)	Operating process automation	Adoption of Robotic Process Automation (RPA) will enable companies to improve productivity and responsiveness and seek increased agility, which will lead to labor cost reduction and consistent process execution
	Organizational culture change	With digital transformation, employees' core capabilities (increased proportion of agility and flexibility in relationships) are changing and corporate culture is changing accordingly
	Process efficiency	Companies maximize overall process efficiency by innovating the existing analogue-based or digitalization-based processes through digital transformation
Kim Yong-jin (2018)	BM	When products/services, delivery system and production operating system are digitalized, these businesses require platform technology. Platform technology, which is based on hyperconnectivity and superintelligence, promotes the emergence of new "smart business model" such as O2O (Online to Offline) amid the development of IoT, cloud, and AI
Kim Seung-rae (2021)	Advent of platform economy era	Platform economy refers to platform service, the core of the 4th Industrial Revolution, where various production and consumption occur among each economic player based on digital technology and network.The need for technological expansion and compatibility across society, politics, and economy will increase through digital transformation
Lee Myung-hwa & Choi Yong-in (2017)	Increased importance for convergent talents	Digital transformation requires talents with both cognitive/non-cognitive and social skills, increasing the value of talents with ICT technology, quantification and mathematical capabilities, as well as self-organization, management and communication skills
Kim Seung-rae (2020)	Development of innovation ecosystem	Digital innovative ecosystem means that the existing industrial ecosystem shifts to digital environment base. Digital transformation promotes such development of digital innovative ecosystem (elevating companies with platform or system to leader group and facilitating connection and convergence with other industries)
Lomi et al. (2014)	Changes in organizational form and structure	Acceleration of digital transformation produces new types of systems such as virtual collaboration, online community, open-source project, and Gig economy
Wu et al. (2016)	Supply chain integration	Digitalization of supply chains advances, and information-sharing and decision-making coordination become sophisticated. Such sharing of information becomes a basis for integration Risk, cost, and profit are shared by coordination to the next step and sharing of sources, and connection of organization

(Economic/social impacts of digital transformation) The impacts of digital transformation are widely seen, and this chapter summarizes the impacts of digital transformation in economic and social terms through literature study.

(Analysis overview) This section derives and categorizes* detailed issues by analyzing domestic and foreign news big data related to negative effect of digital transformation through Embedded Topic Modeling**.

* Based on the analysis result of 「Principled AI」 (Harvard Berkman Klein Research Center, 2020), categorize digital transformation's negative effect into eight (privacy, accountability, safety and security, transparency and explainability, fairness and anti-discrimination, human control on technology, professional responsibility, promotion of human values).

** Use of LDA topic model harnessing pre-trained language model (distiluse-base-multilingual-cased) in BERT architecture.

※ (Regarding news big data selection) Since risk issues of digital transformation are relatively recently highlighted, relevant papers and patents are insufficient, and news data is the only quantifiable data that can spot those issues. It is true that news data, which discusses current issues, has its limits in being used for predicting the future. But it is judged that those data can be used as a source to estimate potential issues because we reflected various issues arising from various contexts by collecting/harnessing large-scale domestic and foreign news data. In addition, this study believes that problems such as bias of each media were solved at a certain level by using large-scale news data.

(Detailed issue analysis of digital transformation's negative effect in Korea) We collected and quantitatively analyzed* the case of digital transformation's negative effect ("Iruda") that has become the biggest social issue in Korea, and derived detailed risk issues.

* (Regarding the selection of "Iruda" case) At the beginning of the study, we collected news data for the analysis of negative effect of digital transformation in Korea in the same way as done for major countries. Unlike other countries with abundant news data addressing various related events and topics, news related to "Iruda" was dominant in Korea. Therefore, we took this issue as a representative case of negative effect of digital transformation in Korea, and put a focus in analysis.

Table 3 AI chatbot service "Iruda"

Overview	Controversy	Progress
"Iruda" is an open topic interactive AI chatbot service based on deep learning algorithms developed by ScatterLab's Pingpong Team. It secured about 400,000 users in early January 2021 since its launch in late 2020	Contrary to developer's intention, problems such as privacy infringement, errors in common-sense answers, specific gender hatred, and use for obscene purposes occurred	The service was suspended due to various controversies in January 11, 2021, and PIPC imposed KRW 133 million fine on ScatterLab, the developer of Iruda, for violating Personal Information Protection Act

By matching the results of the quantitative analysis of the Iruda case with the eight negative effects of digital transformation proposed in this study, it was confirmed that privacy infringement types were mentioned the most.

- Ethical issues dominate the negative effect issues of digital transformation in Korea.

[1] Emerging technology information is mainly used to "discover ideas for new R&D projects and tasks planning". To this end, content for technology planning, such as definition and explanation of emerging technologies, related socio-economic issues, technology trends, detailed step-by-step technologies, and challenges, are presented (Lim Hyun et al., 2019)

(Analysis on detailed issues of negative effect from digital transformation in major countries) Deriving detailed risk issues of negative effect from digital transformation covered in media articles in the US, China, Europe, and Japan.

- In major countries, various and complex problems emerge as issues of negative effect of digital transformation.

Table 4 Result of deriving and categorizing detailed risk issues of negative effect from digital transformation with regard to Iruda

Related keywords	Detailed issues	Type of negative effect of digital transformation	Frequency
AI, ethics, problems, controversies, society	AI ethics issue	(As it is common) Matching excluded	293
Hatred, problems, discrimination, women Hatred/sexual harassment	Hatred/sexual harassment	Strengthening of unfairness and discrimination	67
Problems, discrimination, society, hatred, controversies	Hatred/discrimination, controversies	Strengthening of unfairness and discrimination	59
KakaoTalk, use,fines, violation,imposition, behavior	Imposition of fines for use of personal information	Privacy infringement	35
Infringement, Human Rights Committee, AI, technology, development	Human rights violation (by AI technology)	Damage to human values	33
Ethics, AI, professor, seminar, discussion, research	The need for AI ethics research is raised	(As it is common) Matching excluded	32
AI, protection, institutions, come up with, push for	Coming up with AI ethics regulations	(As it is common) Matching excluded	27
Data, person, information, use	Use/protection of personal information	Privacy infringement	24
Remarks, eradication, establishment, in response to, exclude	Eradication of discriminatory/hatred	Strengthening of unfairness and discrimination	16
User, unidentifiable, constant, processing	Unidentifiable processing (of personal information)	Privacy infringement	15
Litigation, claim, law firm, user, filing, unauthorized	Class action/claim for damages (due to unauthorized leakage of personal information)	Privacy infringement	12

Analysis 1	Conduct Embedded Topic Modeling on the entire pre-processed data (cluster the analysis result by relevant topics and match highly relevant media articles to derive a total of nine detailed issues, categorize and analyze them in order of frequency)
Results	It was confirmed that the problem of AI for weapons and bias accounted for a high frequency, followed by problems of deepfakes, IoT device security, and AI ethics
Analysis 2	A frequency analysis of associated technologies by type was performed to identify the digital transformation configuration technology most closely related to the nine issues of negative effect
Results	As with the previous predictions and discussions, AI technology is most closely related to risk issues of digital transformation (estimated as the result of the highest negative effect compared to other technologies because AI technology acts as a core technology in digital transformation)

Table 5 Analysis result of Embedded Topic Modeling (including the analysis of associated technologies by each detailed issue of negative effect)

Detailed topics	Negative effect of digital transformation	Frequency	5G networks	IoT	AI	Big data	Block chain
AI for weapons (AI for weapon)	Safety and security	190	1	10	175	2	2
Bias of AI (biased AI profiling)	Strengthening of unfairness and discrimination	127		10	107	7	3
Deepfake (Facebook banning deepfakes)	Safety and security	71			66	0	5
Security (IoT Inerabilities)	Safety and security	63		60	2	0	1
AI ethics (Ethics in AI systems)	(Matching excluded)	62			61	1	0
Privacy (Data privacy risk)	Privacy infringement	41			17	12	12
Intensified social discrimination of AI (AI discrimination in credit lending)	Strengthening of unfairness and discrimination	11			11	0	0

Analysis 3	Perform Embedded Topic Modeling only for media articles related to AI technology among news data related to negative effect of digital transformation in major countries
Results	Issue of using biometric data took the biggest proportion, followed by security risk, privacy infringement, bias as detailed risk issues involving digital transformation

Table 6 Result of deriving detailed risk issues of AI in major countries

Detailed issues	Negative effect type of digital transformation	Related keywords	Frequency
EU regulations on the use of biometric data	Privacy infringement	EU, Vestager, regulation, commission, regulations, ban, biometric	232
Cybersecurity, cyberattacks/ threats	Safety and security	security, cybersecurity, intrusion, threats, attacks, cyberattacks, risk	165
Racism, bias, and privacy infringement by the use of police surveillance cameras	Privacy infringement, damage to human values	police, recognition, crime, cameras, surveillance, bias, privacy	90
Disinformation and misinformation through the use of Facebook's deepfake videos	Safety and security	deepfakes, videos, facebook, disinformation, misinformation	68
Racial/gender bias algorithm issue	Strengthening of unfairness and discrimination	bias, algorithms, black, gender, race	63

(Comprehensive analysis and implications) To respond to risk issues of digital transformation, the government needs to pay attention to the negative effect that can be derived from AI technology and seek policies tailored to the context.

2. Policy trends in response to risk issues of digital transformation

(Overview) This section summarizes policy trends to respond to risk issues of digital transformation in major countries and Korea into two types (passive/active policyresponse).

(Passive policy response) The US, individual European countries, China, Japan, the Korean government, etc.

The US	The US is promoting low-regulatory policies by announcing the principles and guidelines for the use of AI centering on the Department of National Defense, the White House, and the FTC
Europe-Individual countries	Relevant organizations are established, and policies are implemented in the form of announcing ethical principles, etc. to respond to risk issues of digital transformation
	The UK Parliament established the Select Committee on AI (June 2017) to further consider and solidify the economic, ethical, and social impact of AI development
	Germany Bundesministerium der Justiz und für Verbrauchersc hutz (BMJV) and Bundesministerium des Innern (BMI) in 2018 launched "Data Ethics Committee" that develops ethical standards and guidelines, as well as specific recommendations for actions aimed at protecting individuals, maintaining social cohesion and protecting and promoting prosperity in the information age
	France In 2019, the President announced AI national strategy under the title of "AI for Humanity" (March 29, 2018)
	Italy AGID (Agency for Digital Italy) launched AI Task Force in 2017 (September 2017) and released a white paper "AI at the service of citizens" in 2018 (March 2018)
	Sweden The government released "Artificial intelligence in Swedish business and society: Analysis of development and potential)" that summarizes government assessment needed to develop and use AI
China	Various government agencies and committees present ethical norms/guidelines/principles
Japan	Establishing relevant conference bodies the fastest, compared to other countries to review risk issues, while developing/distributing relevant guidelines
Korea	Korea is supporting digital transformation and related technology/industry development centering on "National AI Strategy (2019)" and "Digital New Deal (2020)" policies, while preparing policies to prevent negative effect of digital transformation

(Proactive policy response) The EU is pursuing an aggressive policy for negative effect of digital transformation.

- (EU: GDPR) The EU enacted (2016) and enforced (2018) the General Data Protection Regulation (GDPR) that is applied to all EU members.
- (EU: AI Act) The AI Act is a bill announced by the European Commission in April 2021, and the main focus is to regulate risks by three types according to the degree of risk that AI poses to humans.

(Comprehensive analysis and implications) Major countries focused on the ambivalence of AI technology and quickly prepared policies to respond to negative effect. To draw up effective policies to respond to risk issues in the future, it is necessary to review various policy measures depending on regulatory levels.

3.Regulation intensity

(Overview) This section reviews legal normative attributes of AI to establish risk response policies for digital transformation and presents policy measures according to regulatory intensity.

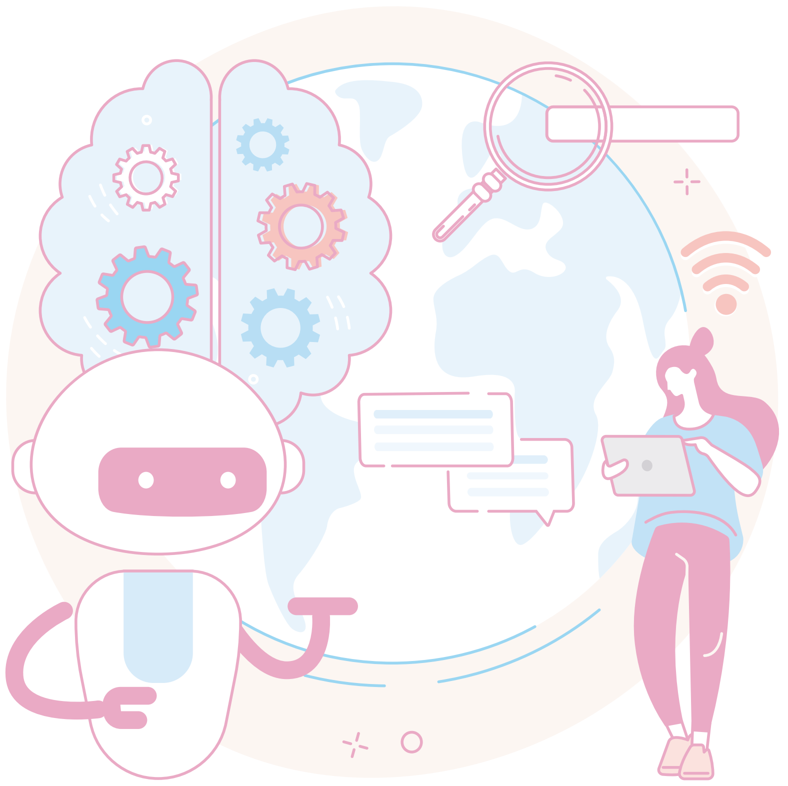
(Review on legal normative attributes of AI) AI technology has limitations in regulations due to legal normative uncertainty of algorithms, and thus future legal responses should be focused on securing transparency of algorithms.

(Analysis on policy scenarios based on regulatory intensity) Suggest and analyze policy measures according to regulatory intensity.

Figure 1 Policy instrument based on regulatory intensity

Policy instrument 1: Experts' ethical approach	Low
Policy instrument 2: Building certification system	↑
Policy instrument 3: Personal rights setting	↓
Policy instrument 4: Setting direct administrative regulation	High

- (Policy instrument 1: Experts' ethical approach) Measures to achieve expert control on their own on the premise of the voluntary participation and cooperation of the expert group.
- (Policy instrument 2: Building certification system) Not a method of directly regulating licensing or regulatory requirements, but a method of inducing voluntary acquisition of certification to establish a response system such as risk management in related fields.
- (Policy instrument 3: Personal rights setting) A regulatory method that allows operators who develop and service algorithms to inform users of the structure and impact of the algorithm, and to request explanations from users' point of view.
- (Policy instrument 4: Setting direct administrative regulation) A method in which the government sets the area available for technology development/services and imposes legal restrictions on other areas.



Core technology and government R&D support for each of four areas in response to infectious disease crisis

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1. Analysis of the status of each of four areas in response to infectious disease crisis

The classification system of core technologies in response to infectious disease crisis is divided into four areas: diagnosis, treatment, vaccine, and quarantine, and detailed classification, definition, and detailed technologies are presented for each area.

Table 1 Classification and definition of core technology and government R&D support for each of four major areas in response to infectious disease crisis

	Classification (Large-Medium)	Definition
1. Diagnosis	1-1. Pathogen resource acquisition and analysis technology	Technology necessary for collection, separation, culture, pretreatment and analysis process, etc. for identification and characteristic research of pathogen resources
	1-2. Diagnosis advancement technology	Advancement of commercialized diagnostic technologies such as molecular diagnostics, immunodiagnisis, and other diagnostic technologies
	1-3. Development of next-generation diagnostic platform technology	Development of diagnostic technologies that have not been commercialized until now
	1-4. Diagnostic performance evaluation technology	Technologies including performance analysis, effectiveness evaluation, verification using clinical samples of the developed diagnostic technology
2. Treatment	2-1. Therapeutic development platform	Technology that discovers candidate substance for new infectious disease treatment, recreate existing drugs, and commercialize them through non-clinical/clinical trials and product development technology
	2-2. Safety and efficacy evaluation	Technology that evaluates safety and efficacy of the developed treatment by regulatory authorities, etc, and tracks the therapeutic effects and side effects
3. Vaccine	3-1. Vaccine platform technology	Technologies related to various types of vaccines such as life/inactivated vaccines and recombinant protein (subunit) vaccines, nucleic acid (DNA/ RNA) vaccines, and viral vector vaccines
	3-2. Supplementary platform technology	Platform technology necessary to enhance efficacy of vaccines or deliver them into the body and to produce and distribute them
	3-3. Vaccine licensing and validation	Technology that verifies safety and effectiveness through non-clinical /clinical trials for vaccine approval and follow-up management and monitoring after inoculation
4. Quarantine	4-1. Prediction and prevention	Technology that predicts risks or spread patterns in advance before infectious disease disaster occurs and that detect them before influx or human infection occurs
	4-2. Preparation	System and management technology for human resources, information, and resources to prepare for the occurrence of infectious disease disasters
	4-3. Response	Technology to reduce damage or end situation early after an infectious disease disaster
	4-4. Restoration	Technology for handling damage that has already occurred after the end of the
	4-5. New quarantine technologies	Technology for handling damage that has already occurred after the end of the

1) Diagnosis

- Diagnostic technology is being advanced through field diagnosis, automation, and multiplex application to shorten the time required for molecular diagnosis such as real-time gene amplification (RP-PCR).

Table 2 Technology trends related to infectious disease diagnosis

Field	Technology Trends
Pathogen resource acquisition and analysis technology	Automated system for sample collection and pre-treatment is under development - Studies are ongoing for automation technology of pathogen concentration, nucleic acid purification, inhibitory factor removal, and identification of unknown pathogens such as medium and non-face-to-face remote sample collection using IoT, drones, robots using next-generation sequencing analysis
Advanced diagnostic technology	Development in the direction of supplementing and improving the shortcomings of molecular diagnosis and immunodiagnosis - Molecular diagnosis can be used from the beginning of infection, and the third-generation PCR, Digital PCR, isothermal amplification method, and diagnostic kits using CRISPR gene scissors technology are currently being developed - As for immunodiagnosis, technology is being developed to measure lower concentrations of antibodies than previous ones, such as aptamer and Digital ELISA, and it is easy to apply to POCT because of diagnosis in a short time

Field	Technology trends
Diagnostic platform technology	Development of multi-diagnosis or high-sensitivity diagnostic technology - With the development of microfluidic technology, a micro system that integrates sample pre-processing, gene amplification, and detection functions into a single chip is being developed
Diagnostic performance evaluation technology	Divided into analytical performance evaluation and clinical performance evaluation - Clinical performance evaluation is for permission and approval of new in vitro diagnostic medical devices, and analytical performance evaluation is for guidelines for quarantine sites and market distribution such as long-term storage and stability

- Although the excellence and potential of domestic diagnostic technology were confirmed in the COVID-19 crisis, expensive equipment such as sample preprocessing and analysis devices, and raw materials, materials, and components such as diagnostic reagents are still less competitive than global companies.

- The government R&D in the field of diagnosis in Korea was invested mainly in the development stage and in diagnostic upgrading technology, and investment in securing pathogen resources and analysis technology is insufficient.

2) Treatment

- Compound-based treatments such as antibiotics, antiviral drugs, immunomodulators, and biopharmaceutical-based treatments such as blood plasma treatments and antibody treatments are the mainstream, and drug re-creation studies of existing treatments are also active.

※Currently, therapeutics have been developed for only a small number of viruses out of 200 viruses, but improvement technologies related to antibody treatments with low toxicity and high specificity and acceleration of drug re-creation using AI are promising in the future.

Table 3 Technology trends related to infectious disease treatment

Field	Technology trends
Compound-based treatment	It is classified into antibiotics to prevent infection of pathogenic bacteria, antivirals to weaken or destroy viruses, and immunomodulators to control immune action, and there are various mechanisms - The development of antibiotics to identify and overcome the problem of resistant bacteria infection* and the development of technologies such as cutting antibiotic-resistant genes through gene editing technology * According to β-lactamase resistance and antibacterial spectrum of antibiotics, cephalosporin and quinolone antibiotics are developed for the 1st to 4th generation - Antiviral drugs are only developed for a small number of more than 200 viruses that cause disease in humans by acting only on viruses of a specific subtype or genotype ※As of 2020, about 90 antiviral drugs, including influenza virus treatment (Tamiflu), Ebola, and coronavirus treatment (remdesivir), have been approved and are being used for 9 types of viruses (The Science Times, 2020) - Immunomodulators contain excessive immunity such as cytokine storms, or on the contrary, immunostimulators that help prevent the progression of infectious diseases or recover by increasing autoimmune
Biopharmaceutical-based treatment	It is a treatment using substances derived from living organisms, including the human body, with low toxicity and high specificity for pathogenic cells, so side effects are small and clinical success rate is high - Plasma therapeutics collect a large amount of immunoglobulin from the plasma of many recovered patients, fractionate, purify and concentrate to produce neutralizing antibodies, and while development is easy, supply is limited and the effect is not uniform - Antibody therapy selects antibodies to specific pathogens obtained from the human body and mass-produces them through cell culture, and can introduce various functions, such as inhibiting antigen binding or destroying infected cells by delivering drugs ※ A variety of immune mechanisms, such as antibody-dependent cytotoxicity (ADCC), antibody-dependent cytotoxicity (ADCP), complement-dependent cytotoxicity (CDC), or various molecules that function similar to antibodies such as double antibody/antibody cocktail, nanobody/nanodicoy, etc. are developed
Drug repositioning	A development method that quickly and efficiently responds to new infectious diseases by applying previously developed drugs to new diseases - A relatively high success rate and short development period (within 3 years) are possible without going through complicated processes such as discovery of new targets, screening and optimization of candidate substances, pharmacokinetic evaluation, and formulation development ※ Many clinical trials have been conducted on existing antiviral drugs such as remdesivir (official approval from FDA) in COVID-19, and 9 out of 14 COVID-19 treatments under development in Korea have repositioned drugs (as of 2021) - Platform technology that accelerates drug repositioning and reduces the risk of failure is actively developed with virtual screening technology that incorporates AI techniques such as deep learning

- The global infectious disease treatment market is expected to grow high in the future, but in Korea, the infectious disease pipeline accounts for only 4.7% of the U.S. and there are no successful cases in developing antiviral drugs.

3) Vaccine

- While the development of gene delivery vaccines such as mRNA/DNA/viral vector vaccines is active, existing platforms such as live and inactivated vaccines and subunit vaccines are still important.

Table 4 Technology trends related to infectious disease vaccine

Field	Technology trends
mRNA vaccine	As the platform that received the most attention in the COVID-19 situation, mRNA expressing the spike protein on the surface of the virus is injected - The biggest advantage of mRNA vaccine is that it does not require a complicated protein production process and can respond relatively quickly to new viruses or mutations if only the base sequence of the virus is known - For the development of mRNA vaccines, stable mRNA molecular design and platform technology for in vivo delivery are important, and the currently developed vaccine uses a carrier in the form of a combination of (Lipid Nano Particle) and PEG - Research has been conducted mainly on Ebola and rabies since 1990. At the end of 2020, the mRNA vaccine developed by Bioentech (Germany), Pfizer (USA), and Modena and National Institute of Allergy and Infectious Diseases (NIAID) in the U.S. received FDA approval for COVID-19 - In Korea, SK Bioscience, GC Green Cross, Estifarm, Jinwon Life Sciences, and I-Gene are promoting the initial development of mRNA vaccines and platform technologies
a DNA vaccine	Produced by inserting a nucleotide sequence corresponding to an antigen into a circular plasmid and amplifying it in large quantities in bacteria - Like the mRNA vaccine, it utilizes a protein production system of cells, has a simple production process and a short development period, and has the advantage of easy storage and transportation due to the structural stability of DNA and no need for a separate carrier - In the body, it has to enter the cell nucleus and undergo a transcriptional process, so it is more complicated than mRNA, and has the disadvantage that the efficacy of antigen production, immune response, and preventive effect is low in clinical practice so far - There are no cases approved for humans so far, but studies are active on MERS, human papillomavirus (HPV), hepatitis B, etc., and a vaccine for West Nile virus in horses was approved in the United States in 2005 - In Korea, Genexine (GX-19), Jinwon Life Sciences (GLS-5310), and Inovio-International Vaccine Research Institute (INO-4800) are developing DNA vaccines for COVID-19
Virus Vector Vaccine	The genetic information (DNA) of the antigen is packaged and delivered in capsid, a protein shell of other viruses* that is not pathogenic or toxic * Vaccinia virus, poliovirus, adenovirus, lentivirus, etc. are used - Virus vector vaccines have been developed to the clinical stage for MERS, Zika, and tuberculosis vaccines, and have been approved for use against Ebola - AstraZeneca and Janssen have developed a virus vector vaccine that uses adenovirus as a carrier for COVID-19, and Cellid-LG Chemical and others are also developing a virus vector vaccine in Korea
Subunit vaccine	It is also called a synthetic antigen vaccine or recombinant protein vaccine, and it produces only surface antigen proteins of the virus by genetic recombination and induces an immune response by direct injection - A platform mainly used for various viruses such as hepatitis B, influenza, acellular Pertussis (aP), and human papilloma virus (HPV) - It has the advantage of high safety and reliability because it has been proven for a long time, but generally has lower immunogenicity than live and inactivated vaccines.Therefore, it is formulated with various adjuvants to enhance immune response - Novavax is a subunit vaccine administered with an adjuvant by recombining spike protein of the COVID-19 virus, and SK Bioscience and Ubiologics are developing a subunit vaccine for COVID-19 in Korea
Live vaccine, inactivated vaccine	Live pathogens are subcultured for a long time in fertilized eggs, animal cells, etc. to remove toxicity (live vaccine), or viruses or microorganisms that cause infection are killed through heat or chemical treatment and injected into the body (inactivated vaccine) - Live vaccines have the advantage of inducing immunity in small amounts and long duration, so they are applied to MMR (measles, mumps, rubella), chickenpox, shingles, Japanese encephalitis, influenza, rotavirus, yellow fever, polio, tuberculosis (BCG) - Inactivated vaccines are used in vaccines such as hepatitis A, polio, J apanese encephalitis, rabies (airborne disease), etc. - Regarding COVID-19, China (Sinopharm and Sinobaek) and India (India Serum Research Institute) are developing live and inactivated vaccines, but high-level safety and special facilities are required to cultivate high-risk viruses

- Due to the lack of core source technologies related to vaccine platforms, the government has recently intensively supported the development of platform technologies such as mRNA vaccines through government R&D.

- As of 2019, the global vaccine market accounted for only 2% of the total drug market due to the burden of phase 3 clinical trials necessary for vaccine development (Medical Times, 2022).

- Despite recent advances such as biosimilars, Korea lacks experience in developing blockbuster vaccines and self-sufficiency in vaccines.

4) Quarantine

- It is divided into disaster response stages such as prediction/prevention, preparation, response, and recovery. It has high publicity and is actively applied to convergence technologies such as ICT.

Table 5 Technology trends related to infectious disease quarantine

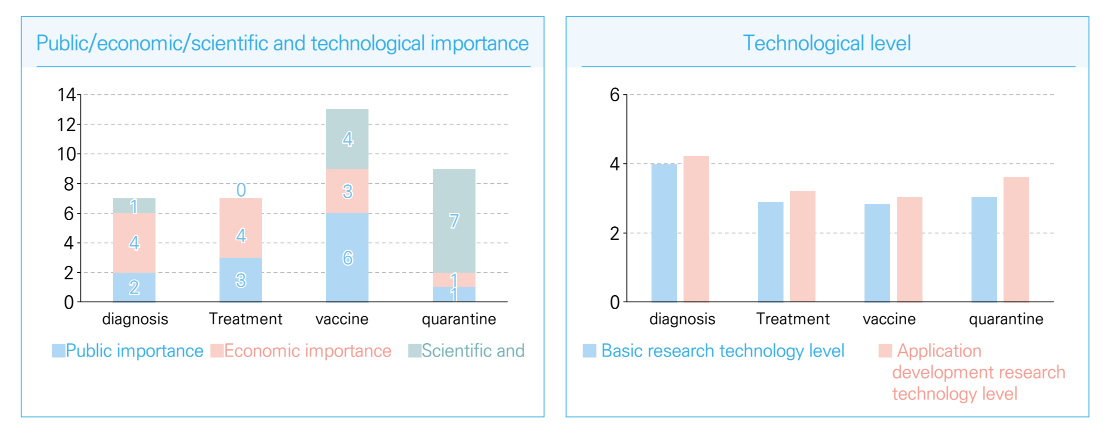
Field	Technology trends
Prediction/prevention technology	Development of technologies such as analysis systems and equipment to predict the spread, mutation, and occurrence of damage in the event of an infectious disease crisis, and to monitor and block inflow from outside - (Development of predictive model) Development of a technology that predicts the risk, spread, and mutation of pathogens based on big data, AI, and mathematical models, and analyzes the scale of damage and the effect of quarantine policies ※ AI can be used to predict the spread of an infectious disease in advance based on big data such as media reports, SNS, or aviation data, or predict the scale of damage caused by the spread of an infectious disease and help determine quarantine policies through a mathematical model - (Monitoring and quarantine technology) Development of equipment and monitoring systems such as thermal imaging cameras to monitor pathogen infection or block the inflow of external infectious diseases in public facilities such as airports ※ Develop a platform to reduce errors in thermal imaging cameras and thermometers and use AI to check risk information in specific areas or manage visitors
Preventive technology	Development of an emergency response system* for efficient and prompt on-site response or big data and ICT-based technologies necessary for managing infectious disease response resources and information in the event of an infectious disease disaster * National Disaster Management Information System (NDMS), etc.
Response technology	Testing and diagnosis technologies such as screening clinics and AI image diagnosis to help diagnose suspected infections, epidemiological/tracking technologies* to track the route and movement of confirmed cases, and technology to isolate/treat confirmed or suspected cases**, etc. * Location tracking through mobile communication, GPS, etc. applies encryption technology for personal information protection ** Negative pressure ward, ventilators, personal quarantine items such as masks and protective clothing, disinfectants, etc.
Recovery technology	After the epidemic of infectious diseases, long-term follow-up investigations on complications and psychological effects caused by infectious diseases, or guidelines for safety management, etc.

- Korean government's investment in quarantine technology has totaled 243.9 billion won over the past five years ('15-'19), with an annual average increase of 48.8 billion won (17.0% annual average increase).
- Quarantine technology has a weak base of related industries, such as corporate participation, mainly in public demand, and there are restrictions on access to and utilization of personal information in tracking and monitoring the movement of confirmed patients.

2. Response to infectious disease crisis Major issues and strategies to secure core technologies in each of the four major areas

- Focused Group Interview (FGI) was conducted for industry, academia, and research experts (12 people) on the importance and technological level of each of the four major areas in responding to the infectious disease crisis, major issues and investment priorities, and strategies to secure core technologies.

Figure 1 Research on the importance and technological level of each of the four major areas of infectious diseases



1) Diagnosis

- **(Issue)** Although domestic companies' technological competitiveness has improved thanks to investments made so far, resulting in global exports in the COVID-19 pandemic, but the lack of diagnostic platform technology, various markers, and technological diversity suitable for the diagnostic target are obstacles.

Table 6 Major issues in infectious disease diagnosis

Major Issues	Response (cases)
Lack of platform technology and technology diversity	6
Lack of verification and utilization of new technologies such as rapid diagnosis kits	4
Excessive regulations and lack of regulatory science research	4
Lack of opportunities for cooperation between industry, academia, and research institutes	3
Lack of link to practical use due to excessive focus on thesis performance	2
Lack of professional personnel	1

• (**Investment priority**) In terms of scientific, technological, economic, and public importance, "vaccine platform technology" is the most important technology to invest inIt was found to be high, and economic importance was high in "diagnosis advanced technology" and "development of next-generation diagnostic platform technology".

• **(Strategy to secure core technology)** While continuously investing in "development of next-generation diagnostic platform technology" through original technology research, the government should focus on "pathogen resource securing and analysis technology" with high public importance, and the private sector should promote "advanced diagnostic technology".

2) Vaccine

• **(Issue)** Government R&D investment has increased by 20% annually over the past five years ('15-'19), and has been increasing at a high rate even after COVID-19, but it is urgent to secure global technological competitiveness and vaccine.

Table 7 MMajor issues in the field of infectious disease vaccines

Major Issues	Response (cases)
Lack of R&D support such as basic and source research	8
8 long time for clinical trials and approval	7
Lack of experience in domestic in-house vaccine development and marketability	4
Concerns about the efficacy and safety of new vaccines	3
Lack of international cooperation and participation in global networks	3
The difficulty of obtaining patents for new technologies	2

• **(Investment priority)** In terms of scientific, technological, economic, and public importance, "vaccine platform technology" was answered as the technology that should be invested with the highest priority.

• (**Strategy to secure core technologies)** In the face of the lack of domestic original technologies of vaccine development companies, various vaccine platform technologies are constantly developed through basic research by academia and research institutes through government R&D projects.

3) Treatment

• **(Issue)** In addition to vaccine technology, domestic technology level is lower than overseas, long-term investment in basic and basic research and promising candidate substances are insufficient, and industrialization linkage such as corporate support is insufficient.

Table 8 Major issues in the field of infectious disease treatment

Major Issues	Response (cases)
Lack of promising candidate substances	4
Lack of long-term investment in basic and underlying research	4
Lack of industrialization linkage such as corporate support	4
Lack of efficacy evaluation technology	3
Long-term, high-cost clinical trials and licensing burden	2
Lack of domestic self-development experience	2
Lack of efficacy against mutated viruses	1

• **(Investment priority)** The importance of the treatment development platform was high in terms of scientific and technological importance and overall importance, and the safety and efficacy evaluation was evaluated as equally important in terms of economic and public importance.

• **(Strategy to secure core technology)** Continuing basic and source research on antiviral drugs that are absolutely lacking in capabilities of domestic companies, supporting the development of antibiotic new drugs that are difficult to develop due to low commercial efficiency, and continuing to advance the platform for rapid screening and drug re-creation technology.

4) Quarantine

• **(Issue)** Lack of system and manpower for emergency response, pointing out that predictable quarantine policies based on clear scientific evidence and standards are needed and the level of information disclosure is insufficient compared to overseas.

Table 9 Major issues in the field of infectious disease quarantine

Major Issues	Response (cases)
Lack of scientific basis for quarantine policy	5
Lack of systems and manpower for emergency response	4
Insufficient field application and practical use of research results	3
Blocking foreign inflows and lack of international cooperation	2

• **(Investment priority)** In terms of scientific and technological importance, it appeared in the order of prediction, prevention, and new quarantine technologies, and in terms of economic and public importance, it appeared in the order of response technology, prediction/prevention.

- **(Strategy to secure core technologies)** The government needs to provide research resources or infrastructure necessary for the development of quarantine technology to companies, industry-academia-research cooperation is essential for the development of convergent technologies.

3. Conclusions

Supporting strategies of each of four areas in response to infectious disease crisis

- **(Diagnosis)** Need to develop corporate support strategies and platform technologies to expand the competitiveness and ripple effects of K-Diagnosis technology, which is currently limited to some areas.

Table 10 A Step-by-Step Support Strategy for Infectious Disease Diagnosis Area

Classification	Support strategies
Short-term	The diagnostic technology is relatively high in the technology level of domestic private companies, and in the short term, the government's role is focused on supporting companies such as clinical trials and providing samples and information
Mid-term	Investment is needed to improve existing platform technologies such as automation and reduction of time required in relation to the most widely used real-time gene amplification (RT-PCR) technology
Long-term	It is necessary to develop field diagnosis technologies such as isothermal amplification and nano biosensors, and next-generation diagnosis platforms such as multiplexes and genetic scissors

- **(Treatment)** AI technology, drug re-creation technology, and basic and source research support are needed to secure promising candidate substances due to weak global competitiveness and lack of independent pipelines.

Table 11 A Step-by-Step Support Strategy for Infectious Disease Treatment Areas

Classification	Support strategies
Short-term	Invest in platform technologies applicable to various diseases such as drug re-creation and antibody treatments first, but support pipeline development in phase 1 clinical trials and ease regulations such as approval FAST TRACK
Mid-term	Support for R&D by expanding investment in candidate material derivation technology using artificial intelligence and providing a compound library for drug re-creation
Long-term	Continuously invest in new platforms such as PROTAC [1], RNAi [2] and expand investment in basic and source research for infectious diseases

[1] Proteolysis targeting chimera

[2] A technique that inhibits the expression of a specific gene and protein synthesis by selectively decomposing the corresponding specific mRNA using miRNA or siRNA, which is a short, harmonically synthesized RNA

- **(Vaccine)** In order to secure core source technologies and take a leap forward in vaccine production, it is necessary to expand production capacity, accumulate clinical development experience, and joint international research and manpower exchange.

Table 12 A Step-by-Step Support Strategy for Vaccine Areas for Infectious Diseases

Classification	Support strategies
Short-term	Expanding production capacity through overseas cooperation such as consignment production and accumulating experience in developing various pipeline clinical trials (phase 1 or higher)
Mid-term	Expanding technological competitiveness through international cooperation, securing promising pipelines through open innovation, and securing strategies for avoiding existing patents on promising platforms
Long-term	In terms of national security, R&D investment will continue to expand support for vaccine companies and resolve gaps in basic research and disconnection of support

- **(Quarantine)** The domestic level of IT convergence technology for data utilization is very high and the versatility of component technology is high, and thus institutional support such as private collaboration and mitigation of side effects related to information integration and sharing is needed

Table 13 A Step-by-Step Support Strategy for Infectious Disease Quarantine Area

Classification	Support strategies
Short-term	Establish partnerships with the private sector, such as the government and IT companies, and promote the development of necessary technologies through public demand
Mid-term	Prepare measures to alleviate side effects related to information integration and sharing, and prepare regulations and guidelines through social discussions
Long-term	Maintaining stable and continuous investment in areas with high public need, such as development of quarantine goods and system construction, and encouraging companies in related fields such as IT companies to participate in R&D related to quarantine

6G Communication Technology

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1. Overview

1) Backgrounds

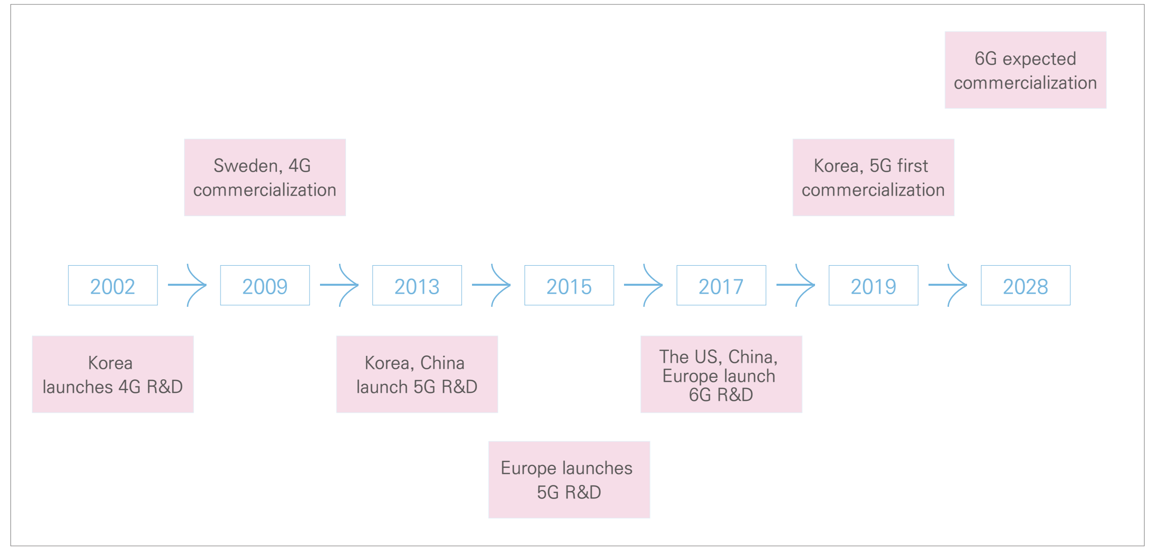
In parallel with the establishment of 5G infrastructure, global advanced countries/companies have initiated related R&D to preoccupy the future 6G telecommunications industry and have recently presented major visions.

- Global companies are actively discussing 6G at the 6G Wireless Communication Summit by presenting a vision and challenges for 6G (2019)[1].
  - (Huawei) Presenting a vision “Connected Things in the 2020s, and Connected Intelligence in the 2030s”
  - (Ericsson) Presenting a vision “Internet of Thought, New computing paradigms”
  - (Nokia) Presenting a vision “Hyper specification·capable·sensing”
  - (Samsung Electronics) Presenting a vision “Internet of Skill, Super eMBB·mMTC·URLLC”
  - (DOCOMO) Presenting a vision “Extreme High data rate coverage latency low energy”

[1] IEEE (2019), 「6G Wireless Summit」

We seek to investigate technology/policy trends and government R&D investment trends in each country and draw implications at the beginning of related R&D to lead the future 6G telecommunications industry.

Figure 1 R&D and Commercialization Flow of Communication Infrastructure in Major Countries



2) Definition and Scope of Technology

1. 6G Future Vision

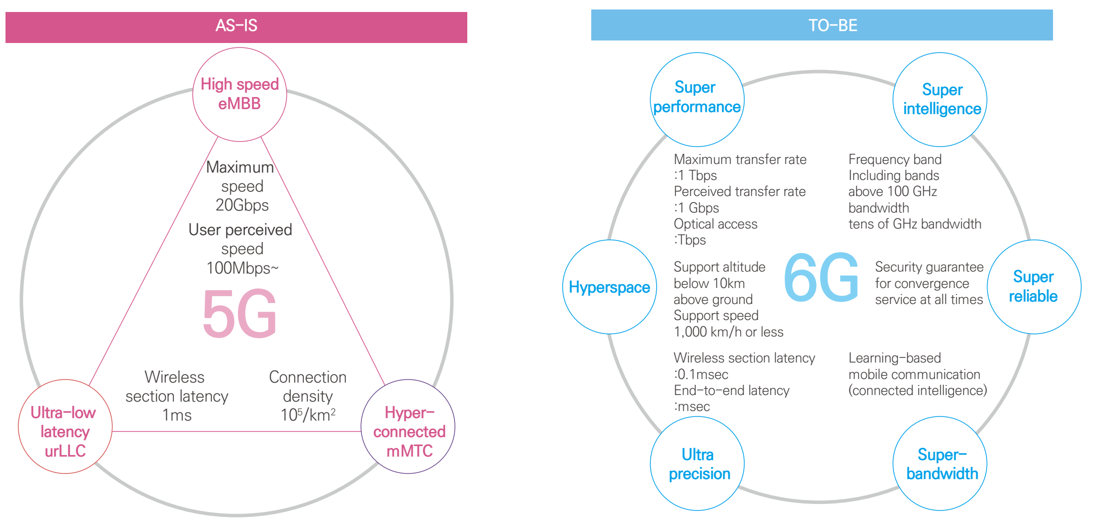
- 5G is expected to evolve into an intelligent communication infrastructure that connects virtual world and reality without space-time restrictions by upgrading 5G performance, optimizing AI-based networks, and expanding coverage such as sea, air, and space.
- (5G performance advancement) Advancement of high-speed, ultralow latency and super connection due to the full-scale spread of 5G services such as autonomous driving, five-sense hologram communication, and remote surgery.
- (Complete network intelligence) Various convergence services are expected to become common in daily life through large-scale collaboration between AI agents based on intelligent wired and wireless communication infrastructure.
- (Transcending telecommunications coverage) Infrastructure that can provide universal wireless communications services, such as sea, air, and space, from existing land-based telecommunications services is expected to become visual.

2. Definition and Classification of Technology

To realize the 6G future, it should consist of six technological characteristics that add hyperspace, super-intelligence, and super-reliability, along with 5G's requirements of ultra-fast, ultra-low latency, and super-connected expansion.

In this paper, we seek to investigate technology/market trends related to the achievement of key performance indicators (KPIs) required for six key indicators.

Figure 2 Key technical indicators of 6G communication



Source: Future mobile communication R&D promotion strategy to lead the 6G era, Ministry of Science and ICT, 2020

Table 1 Technology fields and detailed classification by 6G key indicators

Key indicator	6G KPI	Technology field	Detailed classification
Super high-performance	Maximum transmission rate (1 Tbps), Perceived transmission speed (1 Gbps), Optical access capacity (T bps level)	1. Mobile communication 3. Optical communication	1. Mobile communication ① Tbps wireless communication ② 3D mobile communication ③ Intelligent wireless access invitation
Super-bandwidth	Frequency band (~1 THz), Bandwidth (40 GHz)	2.RF	2.RF ④ THz RF components ⑤ THz frequency
Hyperspace	Support altitude (~10 km above ground), Support speed (~1000 km/h)	1. Mobile communication 4. Satellite	3. Optical communication ⑥ Tbps optical communication
Ultra-precision	Wireless network latency (~0.1 msec), End-to-end latency (~several msec)	5. Network	4. Satellite communication ⑦ 3D satellite communication
Super-intelligence	Learning-based connection	1. Mobile communication 5. Network	5. Network
Super reliable	Security guarantee for convergence service at all times	Security (excluded)	⑧ End-to-end ultra-precision network ⑨ Intelligent 6G mobile core network

※ Security is excluded because it is a subject outside the scope of the infrastructure telecommunications industry to be covered in this paper Source: Preliminary feasibility study report" on 6G Core Technology Development Project", reorganized in June 2020

Table 2 Definition and major core technologies by 6G technology classification

Detailed classification		Definition
1. Mobile communication	① Tbps wireless communication	Core wireless communication technology that provides maximum transmission speed of 1Tbps and user experience transmission speed of 1Gbps via THz ultra-wide band signal bandwidth to realize new services in the future
	② 3D space mobile communication	3D space mobile communication technology to realize unmanned aerial vehicle services that will emerge in earnest within the next 10 years, such as air taxis, smart aviation, and drones
	③ Intelligent wireless access	Intelligent and optimized technology for high-complexity wireless access to accommodate large-scale traffic per unit area and handle complex situations
2. RF	④ THz RF components	Development of RF/antenna components for THz 6G base stations/terminals that operate from 114 GHz to 1 THz and support bandwidths up to 30 GHz, GaN semiconductor process to be applied to realization of the front end, optical-based component technology, etc.
	⑤ THz frequency	Radio channel models and electromagnetic safety assessment technology for base stations/terminals required to design wireless transmission systems as frequencies above 100G and bandwidth of up to 40 GHz that were not used for communication are required
3. Optical communication	⑥ Tbps optical communication	Optical communication source technology to solve problems such as speed/capacity, energy, floor area, latency, and economic feasibility caused by large-scale data traffic of 6G service
4. Satellite communication	⑦ 3D space satellite communication	3D space satellite communication technology required as coverage expands globally using low-orbit and geostationary-orbit satellites
5. Network	⑧ End-to-end ultra-precision network	End-to-end ultra-low latency, high-precision network technology required to guarantee the quality of real-time ultra-realistic services such as 3D hologram, remote control/medical care, etc.
	⑨ Intelligent mobile core network	Intelligent mobile core network technology that can respond to the hyper-distributed and complex network and service environment of the future

Source: Preliminary feasibility study report on "6G Core Technology Development Project", reorganized in June 2020

2. Technology Trends

1) Global technology Trends

1. Tbps wireless communication

- To process 6G traffic called the data big bang, the development of basic wireless communication technologies in the terahertz band, such as modem, protocol, and transmission link, is in progress, and demonstration results are announced under limited circumstances.

2. 3D Space Mobile Communication

- We are developing wireless communication technology using various spatial mobility such as drone base stations, and consider "Extreme Coverage" as one of the 6G requirements.

3. Intelligent Wireless Access

- International standards for intelligent wireless access technology are being studied in 3GPP, O-RAN, etc. for RAN intelligence, machine learning-based wireless transmission, etc.
- In the field of wireless access networks, research on machine learning-based channel estimation, resource allocation, and beamforming is actively underway in the US, Europe, and China.

4. THz RF Components

- Optical element-based single-channel transmit/receive RF components for fixed wireless communication have been developed at the research prototype level mainly in Germany and Japan, and active electron-scanning array structure multi-channel phased array chips are currently being developed[2] mainly by American universities.

5. THz Frequency

- Research on radio wave characteristics and channel modeling in the THz frequency band (0.1 to 0.3 THz) announced analysis results through small-scale field measurement centered on some universities and major advanced research institutes.
- Some universities are conducting research on the effects of THz frequency band electromagnetic waves on the human body, and EMC standards for electromagnetic waves below 40 GHz have recently been established.

6. Tbps Optical Communication

- (Terra-level optical access technology) R&D of optical access structure and transmission related to wireless fronthaul/backhaul for 6G large-capacity data transmission are in progress.
- (Terra-level indoor network technology) R&D of indoor DAS and wireless optical communication are in progress to accommodate 6G large-capacity data and expand coverage based on optical communication in indoor environments.

7. 3D Space Satellite Communication

- With the creation of a growth environment for the satellite communication industry, global companies are actively competing for space Internet based on huge capital[3]
- (Terminal antenna) Development of Ku-band phased array antenna capable of electronic beam steering and polarization control is in progress for satellite communication terminal antenna.

[2] Journal of the Institute of Electronics Engineers of Korea (2020),「RF Technology Trend in Preparation for 6G Communication」
[3] Jointly related ministries (2021),「Development Plan for Micro-satellite and 6G Satellite Communication Technology」

Table 3 Representative companies and projects for low-orbit satellite network construction[4]

Operator		SpaceX	Telesat	Amazon	OneWeb
Project title		Starlink	Telesat LEO	Kuiper	OneWeb
Number of target satellites		12,000	298	3,236	47,844
Method		Internet service			Partnership with ground carriers
Start of service	Number of satellites	1,584	78	1,618	74
	Time	2020	2022	2026	2021
	Region	The US, part of Canada	Canada	-	Part of the US
Average speed		5.36 Gbps	22.74 Gbps	-	2.17 Gbps
Frequency		User: Ku / GW: Ka	User: Ka / GW: Ka	User: Ka / GW: Ka	User: Ku / GW: Ka

※ Facebook (Athena), Leosat, Google (Loon), Kepler Communications, and Apple are also pursuing projects

8. End-to-End Ultra-Precision Network

- Technologies and international standards are being developed to expand the scope of ultra-low latency and high-precision services such as time-sensitive networking (TSN*) and systems launch for small NFC networks, metro forwarding networks (MTN**), and time-definite networking (DetNet***).
  - * TSN (Time-Sensitive Networking): Ethernet-based networking technology that quickly delivers information between end-to-end networks in a small local area network within a fixed time without loss.
  - ** MTN (Metro Transport Network): Circuit transport network technology for ultra-low-latency transmission of 5G radio access traffic in a metro network based on flexible Ethernet.
  - *** DetNet (Deterministic Networking): Networking technology that quickly delivers information within a fixed time without loss in a single operator management network based on L3 such as IP and MPLS.

9. Intelligent Mobile Core Network

- Basic research is underway on various elemental technologies for the evolution of mobile cores, such as decentralization of mobile core network functions, software, and AI internalization.

2) Domestic Technology Trends

1. Tbps Wireless Communication

- Research on Tbps-level wireless communication technology using THz band, a new frequency band, is conducted by domestic companies and the government to process 6G traffic.

[4] Jointly related ministries (2021),「Strategy for Developing Satellite Communication Technology to Prepare for the 6G Era」

2. 3D Space Mobile Communication

- Domestic mobile communication operators and academia are developing various mobile base station technologies and UAV/UAM related technologies.

3. Intelligent Wireless Access

- Although AI is used very limitedly in existing 5G communication, AI application is considered from the early stages of development in 6G.

4. THz RF Components

- Unit parts such as optical and electronic device-based terahertz signal generators/detectors have been developed, but high-integrity multi-channel beamforming chips based on silicon semiconductor process for mass production are in the early stages of development.

5. THz Frequency

- Basic research on the radio wave characteristics and channel modeling of the THz frequency band (0.1 to 0.3 THz) are being conducted by the research institute and some universities, focusing on short-range and indoor radio waves environments.
- After the commercialization of 5G, research on the effects of electromagnetic waves on the human body and EMC measurement and countermeasure technology is expanding its scope to millimeter wave bands, but THz band requires related research.

6. Tbps Optical Communication

- (Terra-level optical access technology) Domestic industry-academic-research institutes also focus on research on large-capacity and economical optical transmission technology that responds to virtual and open structures.
- (Advanced direct reception technology) Optical interface-based fronthaul technology research and development in progress to accommodate mobile data
- (Terra-level indoor net technology) Promotion of indoor-DAS technology and wireless optical communication technology development

7. 3D Space Satellite Communication

- (Communication payload) Domestic core technology related to antenna development that can change the shape and direction of the beam while the communication payload is operating within the orbit of the satellite.
- (Communication) DVB standard-based satellite communication technology has been secured centering on government-funded research institutes, and research on 3GPP standard-based transmission technology is in progress.

• (Terminal Antenna) Satellite communication antenna/RF technology is on sale as a commercial product, but phased array antenna and core component technology are in the early stages.

8. End-to-End Ultra-precision Network

• Industry has completed the development of commercial chip-based TSN switches, international standardization of DetNet technology, development of DetNet-enabled packet delivery modules and systems, and R&D of DetNet wide-area technology are being promoted jointly by industry, academia, and research institutes.

9. Intelligent Mobile Core Network

• In the early stages of technology research, government-led tasks are planned to begin in 2022, and some large companies present them at the vision and conceptual level.

3. Market Outlook

<6G Communication Market Outlook>

① In the case of 6G communication, which is in the beginning stage of technology development, the market outlook is similar to that of 5G, so only satellite communication, 3D space mobile communication, and 6G networks newly added to 6G are written

② For 5G market outlook, refer to "5G Technology Trend Brief (I. Mobile Communications Network and II. Delivery Network/Access Network)"

<5G Communications Market Outlook>

① According to Ericsson, global sales of 5G-based ICT industry will reach USD1.3 trillion by 2026

② The ripple effect on the domestic economy of 10 major industries related to 5G announced by the KT Economics and Management Research Institute is expected to provide socio-economic value of KRW 25.2 trillion by 2025 and KRW 42.3 trillion by 2030

1) Mobile Communication

• (3D space mobile communication) The 3D space mobile communication market is expected to be formed around UAV and UAM, which are major media and applications.

Table 4 UAV world market outlook

(Unit: billion dollars)

	2019	2020	2021	2022	2023	2024	CAGR
Small UAVs	2.9	3.5	4.22	5.09	6.13	7.39	20.6%
Medium UAVs	3.88	4.52	5.28	6.17	7.2	8.41	16.7%
Large UAVs	4.31	5.07	5.95	6.99	8.22	9.66	17.5%
Total	11.09	13.09	15.45	18.25	21.55	25.46	18.1%

Source: Mordor Intelligence Analysis, 2019

Table 5 UAM global market outlook

Year	2021	2026	2030	2035
Supplied units	-	2,000	62,000	250,000
Market size	-	USD 4 billion	USD 93 billion	USD 325 billion

Source: ETRI Technology Policy Research Division, 2021

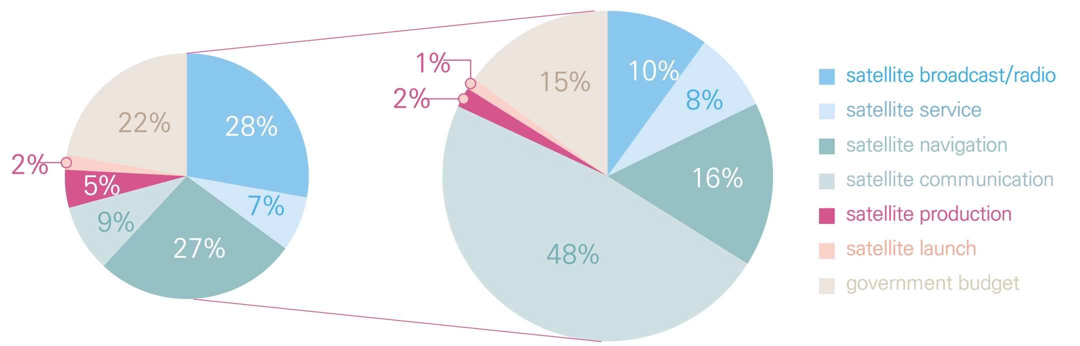
2) Satellite Communication

• The size of the global satellite industry is expected to triple from USD 360 billion in 2018 to USD 1.1 trillion in 2040.

Table 6 Size and outlook of global satellite industry

	2018	Proportion	2020	2030	2040	Proportion
Satellite broadcast/ radio	104,115	29%	107,514	110,554	112,924	10%
Satellite service	24,546	7%	28,219	46,509	84,398	8%
Satellite navigation	98,345	27%	111,195	157,030	177,374	16%
Satellite communication	32,276	9%	39,337	178,168	533,057	48%
Satellite production	16,750	5%	17,711	32,136	20,148	2%
Satellite launch	6,977	2%	7,796	12,143	11,096	1%
Government budget	81,840	22%	85,548	113,195	164,994	15%
Total	364,849	100%	397,320	649,735	1,103,991	100%

Figure 3 2018 → 2040 Market Size Proportion Change



※ Satellite communication market: Total of Consumer Broadband, Network Equipment, and Second Order Impacts
Source: Investment Implications of the Final Frontier(2017.10, Morgan Stanley) Reorganization

3) Network

- (Mobile core network) The 6G cloud-based market is expected to grow continuously, and by subscriber type, the corporate subscriber market will increase significantly.

Table 7 Outlook for global mobile core network market by introduction mode

(Unit: million dollars)

	2020	2021	2022	2023	2024	2025	2026	2027	CAGR
Cloud	506.8	957.8	1,893.6	2,977.7	5,111.1	7,593.3	10,861.4	14,397.5	57.1%
On-premise	204.9	317.3	518.2	680.8	994.0	1,258.5	1,537.0	1,747.6	32.9%
Total	711.7	1,275.1	2,411.9	3,658.5	6,105.1	8,851.8	12,398.4	16,145.1	52.7%

Source: Global 5G Core Market Research Report: Forecast to 2027(Market Research Future, 2021)

Table 8 Outlook for global mobile core network market by user group

(Unit: million dollars)

	2020	2021	2022	2023	2024	2025	2026	2027	CAGR
General user	563.9	958.5	1,697.8	2,361.8	3,586.6	4,603.1	5,491.8	5,706.2	34.6%
Corporate subscriber	147.8	316.6	714.1	1,296.7	2,518.5	4,248.6	6,906.7	10,438.9	79.1%
Total	711.7	1,275.1	2,411.9	3,658.5	6,105.1	8,851.8	12,398.4	16,145.1	52.7%

Source: Global 5G Core Market Research Report: Forecast to 2027(Market Research Future, 2021)

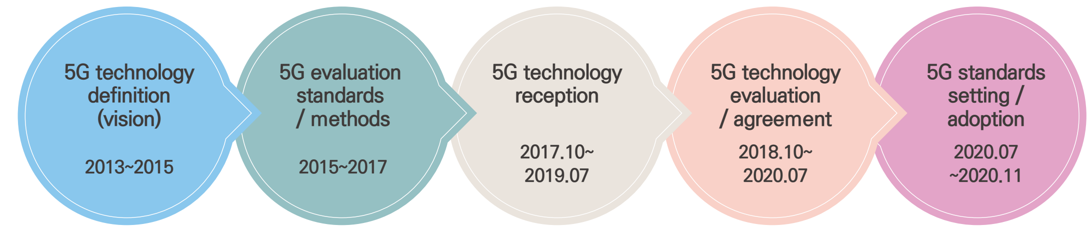
- (Ultra-precision network) Network-based industrial intelligence and advancement are being pursued in various fields, and as a result, the ultra-low latency and high-precision network market is expected to grow explosively.

4. Policy Trends

1) 6G Standardization Trend

- ITU-R started working on 5G standardization in 2013, immediately after 4G approval, and completed the adoption of 5G standards in November 2020, seven years after establishing vision and standards, and receiving and verifying technology.

Figure 4 ITU 5G mobile communication technology standardization process



Source: 5G International Standardization Results <Focusing on the Results of the ITU-R WP5D International Conference>, Lim Jae-woo, March 2021

- GPP, which develops actual standard technology, is currently working on 5G+ standards, and is expected to start 6G standardization around 2023 in consideration of the ITU-R 6G standard schedule.

Overview of International Standardization Organizations

· ITU confirms that the results submitted by the global standards organization meet the criteria presented by the ITU and announces the technology as an ITU recommendation.

· The 3GPP standards developed by the unincorporated standard development partnership project (3GPP) with a total of seven participating standardization organizations* and about 700 companies** have been established as standards for each country. The results were submitted to an the UN-affiliated ICT, an international organization related to technology.

* (Korea) TTA, (Europe) ETSI, (The US) ATIS, (Japan) ARIB/TTC, (China) CCSA, (India) TSDSI
** About 700 companies in Europe, the Americas, and Asia, including Samsung Electronics, LG Electronics, and Qualcomm

2) Global Policy Trends

- Until now, countries around the world have been fiercely competing to preoccupy 5G standardization, preparing policies and basic research to lead 6G technology.

1. The US

- DARPA, a research institute affiliated with the Ministry of National Defense, announced the start of a 6G research project in earnest (2017.5).
- The U.S. Federal Communications Commission (FCC) established Spectrum Frontiers (2016.7) and Spectrum Horizons (2018.2) policies and proactively explore mm-wave and THz frequency bands and promote new services.
- As a candidate, Biden pledged to invest USD 300 billion over four years in R&D of advanced technologies such as AI, semiconductors, and 6G to establish global technology leadership (2021).

2. China

- Immediately after 5G commercialization (2019.11), the Ministry of Science and Technology, the Ministry of Industry and Information Technology, and the Ministry of Education held a ceremony to declare the launch of national 6G technology research (2019.11)[5].

Table 9 Outline of national 6G technology R&D promotion team and expert team

National 6G technology R&D promotion team		Expert team	
Date of launch	Nov. 3, 2019	Date of launch	Nov. 3, 2019
Composition	Officials from 6G related ministries	Composition	A total of 37 experts from universities, researchers, and companies
Role	·Serves as a national control tower in charge of 6G technology R&D ·Establishment of policies leading 6G R&D	Role	·Advice for important decision-making through proposals for 6G technology strategies and technology discussions ·Suggestion of 6G research direction and technical verification

- The Ministry of Industry and Information Technology (MIIT) announced a specific blueprint for 6G R&D in 2018 and started research on core technologies for 6G communication infrastructure with the goal of commercialization by 2030.
- Under the leadership of the Ministry of Science and Technology (MOST), 6G national research related to new network technologies, optical and satellite communications is being promoted every five years from 2018, and an official 6G dedicated organization was launched in 2019.

3. EU[6]

- Arouse the interest of member states to preoccupy 6G leadership, and propose 6G utilization prospects and priorities in the manufacturing and transportation sectors (2020).
- Led by the University of Oulu in Finland, the 6G flagship was established in 2018 and the 6G international conference (Wireless summit) was held every year.

4. Japan

- Prepare "Beyond 5G promotion strategy", a comprehensive 6G strategy based on the technology outlook for 2030 (April. 2020).

Table 10 Functions and major development technologies for Beyond 5G

Function	Main content	Major development technology
High-speed, high-capacity	· Access network communication speed is 10 times that of 5G · Core network communication speed is 100 times the current speed	Terahertz
Ultra-low latency	· Low latency of 1/10 of 5G · Full synchronization of cyber-physical systems · Advanced synchronization with secure network	Spatio-temporal synchronization (including cyberspace)
Ultra-multiple concurrent connections	· The number of simultaneous connections is 10 times that of 5G	Sensing
Ultra-low power consumption	· Low power consumption at 1/100 level of current	All-fiber network; Low Power Consumption Semiconductor
Super safe and reliable	· Ensuring security at all times · Instant recovery in case of disaster and failure	Quantum cryptography
Autonomy	· Automatic connection between autonomously operating devices · Building an optimal network beyond wired/wireless	Fully virtualized
Scalability	· Seamless connection with satellite and stratospheric communication system (HAPS) (including space and marine) · Communication in all places through mutual interworking between devices	HAPS, Inclusive interface

Source: Competition to preoccupy 6G leadership in major countries in earnest, IITP Lee Eun-ok, 2020.7

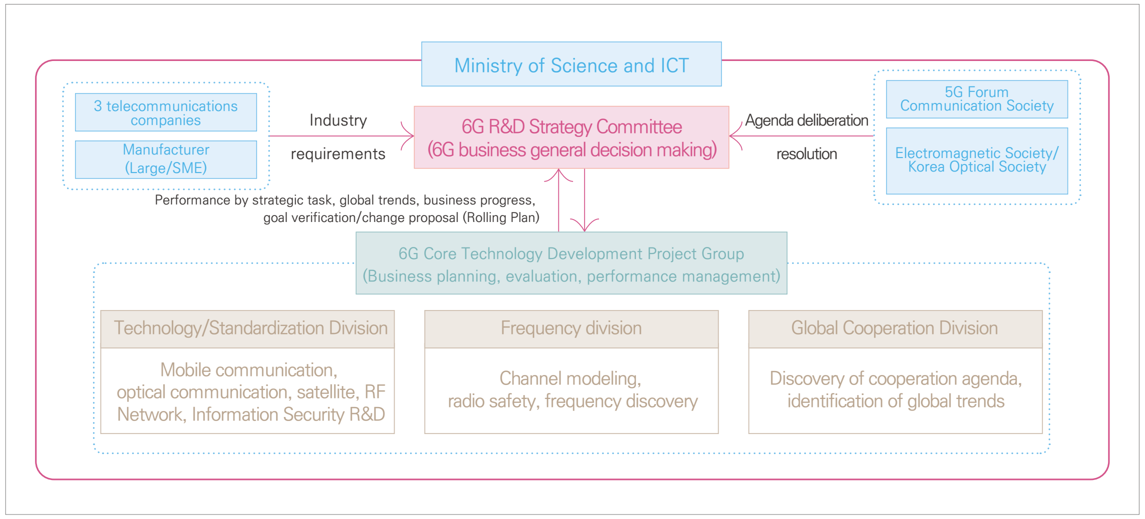
- Meanwhile, the new comprehensive economic measures announced at the end of 2019 also include a post-5G support plan, expressing its will to foster the next-generation telecommunications industry.

3) Domestic Policy Trends

- Establishment of "Future Mobile Communication R&D Promotion Strategy to Lead the 6G Era" in earnest to prepare the foundation for leading the 6G global market (2020) Ministry of Science and ICT (2020)[7].

[5] Ministry of Internal Affairs and Communications (2020), 「Status of Major Global Countries Preparing for the Post-5G Era」
[6] IITP (2020), 「ICT Spot Issue –Major Countries, Full-scale Competition to Preoccupy 6G Leadership」
[7] Ministry of Science and ICT (2020), "Future Mobile Communication R&D Promotion Strategy to Lead the 6G Era" (draft)

Figure 5 6G R&D promotion system



- Establishment of “Satellite Communication Technology Development Strategy to Prepare for the 6G Era” to become a powerhouse in 6G satellite communication technology (2021) Jointly related ministries (2021)[8].
- Establishment of a national strategic 6G development response system, such as signing an MOU with Finland for 6G joint development in 2019.
- In a joint statement after the ROK-US summit, Korea and the US pledged to cooperate to develop future-oriented partnerships by leading innovation in emerging technologies such as 5G, 6G, and Open-RAN technologies (2021.5).
- The MSIT-European Commission held the “Korea-Europe B5G Workshop”on the theme of promoting cooperation in next-generation mobile communication network (2021.6).

[8] Jointly related ministries (2021), 「Strategy for Developing Satellite Communication Technology to Prepare for the 6G Era」

5. R&D Investment Trends

1) Government R&D Investment Trends

- The main government R&D project in the 6G field is the “6G Core Technology Development Project”, which secures the safety of the national network infrastructure and supports the localization of core components of domestic communication terminals and equipment.

Table 11 Current status of major details of 6G core technology development projects

(Unit: million won)

Project title	Period	Mid-term budget status				
		2021	2022	2023	2024	2025
Tbps level wireless communication technology	2021-2025	5,039	5,385	5,792	5,792	5,792
Develop THz band frequency and Safety assessment technology	2021-2025	1,147	2,021	1,712	2,065	1,712
3D space mobile communication technology	2021-2025	962	2,879	3,287	3,570	3,570
THz band RF core technology	2021-2024	2,745	2,712	2,531	2,531	-
Intelligent wireless access technology	2021-2025	2,181	3,654	4,036	4,363	4,145
Tbps level optical communication infrastructure technology	2021-2025	1,831	3,203	3,203	3,432	3,203
End-to-end ultra-precision network technology	2021-2025	1,147	2,582	3,155	3,155	3,155
3D space satellite communication technological	2021-2025	1,352	4,284	4,409	4,409	4,433
Intelligent 6G mobile core network technology	2022-2025		4,063	4,527	4,527	4,063
Total		17,204*	30,783	32,652	33,844	30,073

※ Including KRW 800 million for 2021

Table 12 Current status of major details of 6G core technology development projects

Project title	Organizer	Participants		Research stage	2021budget (million won)
			Institution		
Development of sub-THz band wireless transmission and connection element technology that supports 6th generation Tbps data rate	KAIST	Industry	LG Electronics and one other	Applied research	800
		Research institute	KRISS		
Development of Tbps level wireless communication technology	ETRI	Industry	Samsung Electronics and 5 others		4,239
		Academia	Dankook University and 4 others		
		Others	Korea Network Industry Association		
Development of THz band frequency and safety assessment technology	ETRI	Industry	Samsung Electronics	Applied research	1,147
		Academia	Korea University		
Development of 3D space mobile communication technology	ETRI	Academia	Inha University and one other	Applied research	962
Development of THz band RF core components	ETRI	Academia	Daegu University	Applied research	2,245
Development of core technology for 6G RF shear based on low-power MIMO and high-efficiency space synthesis QAM	Sungkyunkwan University	Academia	Seoul National University and one other		500
Intelligent wireless access technology development	ETRI	Academia	Pohang University of Science and Technology and 2 others	Applied research	1,681
Intelligent 6G wireless access system	Korea University	Academia	Ajou University and 2 others	Basic research	500
Development of Tbps-class optical communication infrastructure technology	ETRI	Industry	OE Solution and 3 others	Applied research	1,831
		Academia	KAIST		
End-to-end ultra-precision network technology development	ETRI	Industry	KT and 4 others	Applied research	1,147
		Academia	Sangmyung University and 2 others		
Development of 3D space network technology / 3D space satellite communication technology	ETRI	Industry	KT and one other	Applied research	1,352
		Academia	Chonbuk National University and 1 other		
Intelligent 6G mobile core network technology	Undecided				

6. Conclusion

1) Policy Proposal

- 6G summary
  - To make 6G communication popular, it is important to develop connection with related services. In addition to 6G core technology development, it is necessary to develop new 6G-based intelligent service technology.
  - To form a virtuous cycle ecosystem that is led by the government in the early stage and private investment in the mid-term, a strategic approach is needed to jointly develop technologies with private companies participating from the beginning of government R&D. Also, it is necessary to secure commercial technologies led by private companies after the start of standardization.
  - Since securing the standardization initiative based on domestic superior technology is the first step in preoccupying the 6G market, efforts are needed to strengthen the connectivity and expand the base so that technology development can lead to standards and patents.

- 3D space mobile communication
  - A preemptive market creation strategy is needed through the expansion of application in the public sector, such as disaster notification oin isolated telecommunications areas and drone patrols.
  - Since it is a field regulated for safety, security, and personal information, it is necessary to establish a legal basis that considers costs and benefits in a balanced way before the industry spreads in earnest.

- THz frequency
  - Long-term/continuous government-level R&D support is required as industrial investment in new radio wave resources may be low due to difficulties in building expensive measuring equipment and permitting test frequencies.
  - Due to insufficient research on the effects of the THz band on the human body, it is necessary to cooperate with related organizations and promote related R&D to ensure public safety.

- Network
  - Domestic network equipment companies that promote commercialization based on available chipsets due to lack of R&D investment capacity need technical support through basic research on innovation/challenge of academic and research institutes to secure differentiated technological competitiveness.
  - Although the direction for the core network is derived, the detailed structure will be presented at the time of full-scale standardization in the future. Therefore, it is necessary to preemptively secure IPR through research on various structures.

Quantum Information Technology

• Hyungjung Yoo, Associate Research Fellow, Center for Future S&T Planning, KISTEP

1. Technology Trends

1) Quantum Computing

• Quantum Computing is a fast-advancing technology field with a 5 – 127 qubit Quantum Computing System established for each platform. Algorithm and verification research is also actively underway.

- (Algorithm and verification) To enhance quantum computer's computation speed dramatically, the focus of research is solving meaningful problems, such as annealing, using NISQ*, and efficient error correction/error mitigation as algorithms for quantum computation.

  * Developing an algorithm deployable in hundreds of qubits-level Noisy Intermediate-Scale Quantum devices (NISQ)

- (System building) Each country has established and announced various methods of Quantum Computing systems. Among others, China has proved Quantum Supremacy with two methods of a Quantum Computing system.

2) Quantum Communication

• Research is underway to extend the range of QKD communication, a technology that comes closest to application. Also, other research is actively ongoing to utilize existing fixed-line fiber optic networks with quantum repeaters and memory.

- (Quantum Cryptography) Wired and Wireless Network Communication technologies, such as Quam Random Number Generation, Quantum Random Number Generation (QRNG), and Quantum Secret Sharing (QSS) are the most advanced technologies in terms of commercialization, and distance extension study is ongoing.
- (Quantum Teleportation)- A technology that transfers quantum information from one location to another location based on quantum entanglement, and research is on the direct transfer of information and deployment in a test network.
- (Quantum memory and repeater) A technology that repeats and stores quantum signals by storing quantum entanglement status in an intermediate node and using entanglement exchange technology to extend the transmission distance of quantum signals.

3) Quantum Sensing

• R&D is ongoing to achieve precision, or accuracy, beyond the existing limit* by utilizing quantum characteristics, such as quantum entanglement or squeezing

  * Standard quantum limit or shot-noise limit[1]

- (Inertia, Gravity) Through atom-photon interactions, researches on measuring gravity, acceleration and spinning speed, miniaturization, and low power consumption are underway. Highly likely to be used for defense technologies.
- (Electromagnetic field) Ultra-high performance magnetic field sensors (magnetic sensor) are mature research fields, and many application studies have been conducted, including biomagnetic fields. Recently, the impurities* in solid-state magnetic field sensors is a new mainstream research field.

  * The target is to reach the magnetic-field sensitivity below 1 pT· Hz-0.5 using Diamond NV(nitrogen vacancy)

- (Time and frequency) A technology to measure time and frequency using the superposition and interference of two quantum states by light. Atom clocks are commercially available in broad applications, such as communication, navigation, and exploitation of natural resources.
- (Light and Imaging) This technology's ultimate goal is to use MRI and microscope, measuring the sensitivity of ultra-high resolution and standard quantum beyond the limits of classical physics through characteristics of a quantum state of light.

[1] https://wiki.quist.or.kr/index.php/Quantum_Sensor_(Quantum_Sensor) refer to 2.3.1

2. Industry Trends

1) Quantum Computing

- (IBM, USA) It provides a superconducting computing service on cloud, or IBM Q. It has announced the roadmap for the practical applications of quantum computing in new modular architecture and networking.

- (Google, USA) It proved Quantum Supremacy with a 54-qubit Sycamore superconducting processor (Oct. 2019). Since then, it has significantly advanced its performance and unveiled a plan to develop a commercial quantum computer (May 2021).

- (Intel, USA) It has conducted joint research on semiconductor quantum dots to check for production feasibility and studied Full-stack* approach, including SW.

  * Including all solutions, such as chip, system, SW, and cloud service

  ※ It has built 49 qubits superconducting quantum chip called Tangle Lake, but now shifted focus to spin qubits (quantum dots)

- (Rigetti, USA) It has launched a Full-stack quantum computing service and announced the roadmap for 4,000 qubits.

- (IonQ, USA) Having been co-founded by Chris Monroe, University of Maryland and Jungsang Kim, Duke University in 2015, IonQ is an ion trap quantum computing company and unveiled its roadmap for quantum dots in December 2020.

  ※ Offering 11 qubits quantum computing cloud service through MS, Google and Amazon

- (Quantinuum, USA) Honeywell Quantum solution was merged with COC* , an ion trap-based SW company, to form a new company Quantinuum in June 2021.

  * Cambridge Quantum Computing

  - (Other) Large IT companies have connected cloud services with quantum computing companies or established their own research organizations, and various startups have sprung up until recently[2].
  - (Microsoft, USA) It offers optimal algorithm and quantum program development environment and connects with computing companies.
  - (Amazon, USA) It launched the "Amazon Braket" quantum computing service and newly established a quantum computing organization.

[2] Korea Institute of Science and Technology Information (2021),「Quantum Technology Science Technology Industry Analysis」

- (Domestic) Some large companies are engaged in joint research with overseas partners and established their first startups in Korea.
  - Samsung Advanced Institute of Technology is the only entity that collaborates with IBM in joint research. KAIST founded Qunova, a startup that provides solutions based on quantum computing SW and AI, for the first time in Korea in 2021[3].

2) Quantum Communication

- (Overseas) Companies are competing to secure leadership in the global market through cryptographic communication services and invest in R&D to build a QKD network and a test bed for each telecommunication company.

- (Domestic) SK broadband has successfully implemented quantum cryptography communication technology in the nationwide network covering the range of 800 km for the first time in the world. KT has secured wireless quantum cryptography covering 1 km-range.

3) Quantum Sensing

- Atom clock, gravity, and magnetic field sensors, which are highly expected for applications, such as national defense and exploitation of natural resources, are close to commercialization. Research of startups and multinational companies is at the early stage of commercialization[4].

4) Korea's Participation in Global Standardization

- Korea is taking part in the standardization of quantum computing and communication fields and leading the publication of a White Paper, on quantum.
  - (Quantum white paper) Quantum Information Technology, proposed by Korea Research Institute of Standards and Science (KRISS), was adopted and published in IEC white paper, a step before standardization, and Electronics and Telecommunications Research Institute (ETRI) was designated as SEG chair (Oct. 2022)[5,6].

- ISO/IEC JTC 1SG (Joint Technology Committee 1), prepare documents on activities for quantum computing standardization and QKD's security evaluation methodology.

- Through IEEE P7130, standards for Quantum Computing technology[7] are defined.

[3] Qunova, https://qunovacomputing.com
[4] https://www.kriss.re.kr/gallery.es?mid=a10106030000&bid=0002&list_no=3958&act=view
[5] International Electrotechnical Commission (IEC) (2021)「Quantum information technology」
[6] ZDNet Korea, https://zdnet.co.kr/view/?no=20220606100740

- ISG under European Telecommunications Standards Institute (ETSI) adopts Standardization of Quantum Cryptography.

- ITU-T is discussing standardization of Quantum Cryptography Network, including connecting devices using quantum key and framework and definitions[8].

3. Policy Trends

1) Policy Trends in Major countries

- The USA leads quantum technology controls between countries and the formation of a technology bloc by elevating a committee to enact the world-first quantum act and a comprehensive policy for support[9].
  - To replicate the ripple effect of ARPAnet, the beginning of the internet, the US announced a "Quantum Network/Internet Vision*" in 2020 and a policy to establish five National Quantum Information Science Research Centers with MS, Harvard University, Cornell University, Intel, Lockheed Martin and support the research centers with USD 700 billion in August 2020.
    * A strategic vision for Quantum Networks (Feb. 2020 by NQCQ) and the development of a national quantum internet (Jul. 2020, by Department of Energy)
  - The subcommittee on Quantum Information Science has announced a series of short-term goals as part of national quantum initiatives, such as Quantum Networking Research (Jan. 2021) and Commercialization of Quantum Sensor (Mar. 2022).
  - To beat the competition over technological hegemony against China, the US has enacted the Innovation and Competition Act (USICA) and unveiled a plan to invest USD 29 billion (KRW 33 trillion) in 10 sectors over the next five years. (It passed the Senate in June 2021)
  - Recently, the Biden administration announced a presidential executive order to establish the "National Quantum Initiative Committee" under the White House, elevating the function of the existing advisory committee (May 2022)[10].

[7] 미국전기전자학회(IEEE), https://standards.ieee.org/ieee/7130/10680/
[8] The International Telecommunication Union (ITU), https://www.itu.int/itu-t/workprog/wp_search.aspx
[9] https://www.quantum.gov/
[10] Donga Science, https://m.dongascience.com/news.php?idx=54043

- In China, top leadership's interest is driving investment expansion in the Quantum sector across the nation.
  - In 2006, China announced the Overview of the National mid-and long-term Science and Technology Development Plan (2006-2020), including Quantum Control. It has been implementing Quantum Science and Technology Projects. No specific laws have been enacted to support the Quantum sector.
    ※ The Quantum sector is governed by Law of the People' s Republic of China on Progress of Science and Technology and Law of the People' s Republic of China on Performance Promotion of Science and Technology.
  - The 13th Five-year-plan set Quantum as a strategic area in 2016 and implemented medium-and large projects in the Quantum Communication field. The 14th Five-year-plan proposed to develop Quantum Information Technology in 2021[11].
  - The country has invested in the Quantum Information field through diverse programs, including establishing a research institute and developing human resources.

- Europe has pursued Quantum Flagship Project and unveiled a roadmap for Quantum development at a comprehensive EU level. Each country announced an individual policy suitable for the characteristics of each country, advancing research capabilities competitively.
  - Since launching Quantum Europe Project in 2006, Europe has announced a roadmap for Quantum development along with the "Quantum Manifesto" in which industry, academia, and research institutes participate altogether.
  - UK announced the National Quantum Technology Strategy in 2015 and 2019 to focus on generating industrial results based on the high level of basic science foundation and government-led investment for over 10 years.
  - In Germany, the Federal Ministry of Education and Research (BMBF) announced the "From Quantum technology basic to market program" in Septem 2018 and the Quantum Computing roadmap in January 2021. It developed a guide on Quantum Research Support in March 2021.

- Japan has shifted its focus from investing in basic science-centered programs on Quantum Computing to developing a national strategy and actively participating in the US-led technology block.
  - The National Institute of Information and Communications Technology (NICT) began to develop Quantum Technology in 2010. Since then, the Quantum Science and Technology (QST), a research institute, was established to oversee overall quantum science technology in 2016.

[11] Quantum Information Research Support Center (2022),「The analysis of a system for intensive investment in the National Quantum Research」

- As it constantly announced a national strategy, it has selected and invested in national strategic technologies and research objectives. It also unveiled Quantum Innovation Strategy in January 2020 and Moonshot Program in February 2020[12].
  ※ A technology roadmap sets diverse R&D objectives, including designating a Quantum Innovation Hub, developing a NISQ Quantum Computing System by 2030, and developing a Quantum Computer with error correction.
- Meanwhile, Japan joins the US-led efforts in building a Quantum Technology bloc, such as review on the establishment of a modern-day COCOM*
  *A system that western countries established in 1949 to control the export of strategic materials, aiming to prevent the outflow of technologies that might be used to strengthen communist countries, such as the Soviet Union.

2) Domestic Policy Trends

- Korea announced a pan-government "Quantum Technology R&D Investment Strategy" in April 2021. Since then, it has formed and operated Quantum Technology Special Committee under the National Science and Technology Council in October 2021[13].
  ※ As a follow-up measure of Quantum Technology R&D investment strategy, the Act on the National Science and Technology Council (Article 7) and the Enforcement Decree of the Act on the National Science and Technology Council (Article 10). The National Science and Technology Council was created under the Regulations for Enforcement of the National Science and Technology Council. (Revised on October 19, 2021)
  - Since the Ministry of Science and ICT developed a mid-and long-term implementation strategy for Quantum Information Communication in December 2014, the preliminary feasibility study on the 2016 mid-and long-term Technology Development Project for Quantum Information Communication failed in 2018.
  - As a nation that belatedly jumped into Quantum's R&D, Korea established an R&D investment strategy in 2021 to catch up with advanced countries through efficient investment.
  - The Special Committee on Quantum Technology comprises four technology sub-committees on computing, communication, sensing, and basic and underlying technologies), two application sub-committees (on economy and security), and a working committee.

- Since the proposal of a bill to spur the development and commercialization of Quantum Information Communication Technology in 2017, a bill on the promotion of the development and commercialization of Quantum Technology in 2022 has been proposed and is under review[14].

[12] Korea Institute of S&T Evaluation and Planning (2019),「Quantum Information Science」Trends on policy and technology of S&T and ICT
[13] https://www.pacst.go.kr/jsp/council/councilList.jsp?category_cd=2&group_id=36
[14] Bill Information, https://likms.assembly.go.kr/bill/main.do

Table 1 Implementation goals of Quantum R&D Investment Strategy by phase

Phase	Goals	Highlights
Phase 1 (2021-2024)	Laying the foundation, such as talents development and development of elementary technology	50 qubits Quantum Processor
		Compact fixed quantum cryptography communication
		Sophisticated and compact elementary technology (spatial resolution and precision)
Phase 2 (2025-2030)	PoC of academic and industrial applications (success cases)	NISQ Quantum Computing system
		Ultra-speed, precision wireless quantum cryptography communication (Quantum Drone and Airplane)
		Utilization of Quantum Sensor Industry (semiconductor and medical)
Phase 3 (2031-2035)	Full-blown commercialization of Quantum Technology	Quantum computer with quantum error correction (QEC)
		Quantum Internet technology
		Expanding applications of Quantum Sensor (Ultra long distance telescope, quantum microscopy)

Source: This is recreated referring to Quantum Technology R&D Investment Strategy (draft) by Ministry of Science and ICT (2021)

4. R&D Investment Trends

To grasp the government's R&D investment trends, analysis of major programs in Quantum Information Technology field ('19-'22) and project-level analysis with NTIS keyword search were conducted.

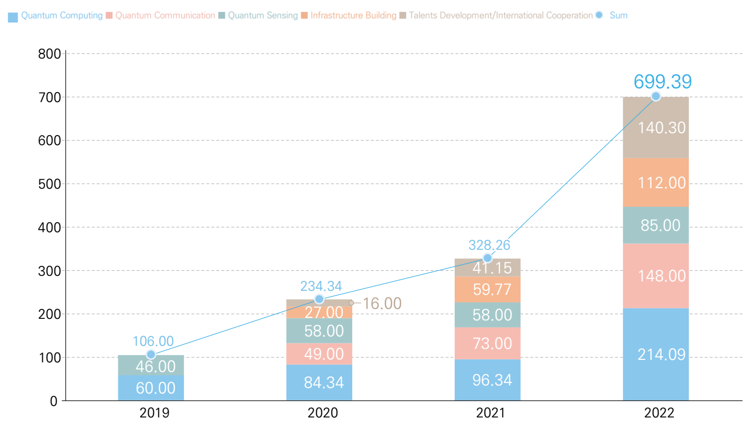
※ Project-level analysis using NTIS may differ in terms of a total amount of support depending on search keywords.
- Project search keywords) - (theory, computing, communication, sensing, material, algorithm) quantum display.

- (Dedicated Program) Quantum Information Technology-dedicated R&D program was drastically expanded from KRW 10.6 billion in 2019 to KRW 69.9 billion in 2022 (up by 113% from 2021).
  ※ Government-funded research institutes' major programs (around KRW 17 billion per year) and non-R&D(Infrastructure Building program for Quantum Cryptography Communication) are excluded.
  ※ Investing a total of KRW 136.8 billion for four years ('19-'22) in Technology Development (KRW 97.2 billion) and Infrastructure Building (KRW 39.6 billion).
  - (Strengthening Adventurous Source Research) Investing KRW 52.2 billion for three years in R&D of Quantum Computing, Quantum Communication and Quantum Sensing, and additionally investing KRW 10 billion in Computing R&D and KRW 7.2 billion in Communication R&D, and KRW 2.7 billion in Sensing R&D in 2022
  - (Building Quantum-specialized infrastructure) Providing KRW 19.9 billion in the construction of Quantum Fab and Overseas Cloud Use ('19-'22).

- (Developing professional workforce and establishing domestic and overseas cooperative systems) Funding KRW 14.6 billion for three years in talents development and international cooperation and new funding for a general R&D program in the Quantum Technology Cooperation field in 2022.

Figure 1 Investment Status by Technology Development, Infrastructure and Talents Development/International Cooperation

(Unit: KRW 000 million)



- (Project Criteria) The total R&D expense in Quantum is on a steady increase in line with the investment expansion of dedicated programs from KRW 30.8 billion in 2016 to KRW 75.1 billion in 2020.

※ Please note that infrastructure building, talents development, and international cooperation are all included in the technology sector for analysis without distinction. And basic projects, such as materials and theories that are applicable to all other areas are included in Quantum Computing.

- (By technology) Annually, the number of projects in Quantum Computing, Quantum Communication, and Quantum Sensing, as well as the total R&D expense is increasing.
- (By ministry) The Ministry of Science and ICT runs 94.2% of programs.

Table 2 Status on investment in Quantum Information Technology by Ministry

(Unit: KRW 000 billion)

Classification	2016	2017	2018	2019	2020	Total
Ministry of Science and ICT	298.00	389.44	405.80	562.96	688.70	2,344.90
Ministry of Education	10.82	11.56	14.16	29.71	31.40	97.65
Ministry of SMEs and Startups	-	0.93	4.18	4.59	13.45	23.15
Other (Ministry of Health and Welfare, Ministry of Trade, Industry and Energy, Defense Acquisition Program Administration)	-	-	0.32	7.03	17.50	24.86
Total	308.82	401.93	424.46	604.29	751.05	2,490.56

Future Direction of Mission-Centered National Innovation Policy

Summarized by KISTEP from 146th KISTEP Wednesday Forum

1. Discussion background

- The Wednesday Forum is held regularly to analyze the current status of various S&T fields, diagnose problems, and find countermeasures. The 146th forum will discuss the future direction of the mission-centered national innovation policy.
- As the importance of problem-solving through innovation is emphasized, the Mission-Oriented Innovation Policy (MOIP), which puts solving social challenges at the core of the policy, has emerged.
  - This is a transformational innovation policy to resolve problems faced by each industry factor or to solve social problems related to each sector.
  - Unlike policies that only aim at economic growth, solving social problems is the top goal in transformational innovation policies, and economic growth is expected to follow as additional benefits.

- Innovation policy is an abbreviated expression of the science and technology innovation policy (STI Policy) encompassing science, technology, and innovation policies, which is a comprehensive and integrated socio-economic policy with a very wide range and is characterized by a mixture of policies in various fields.
  - The science and technology innovation policy started to develop as the British scientist and sociologist J.D. Bernal's book 'The Social Function of Science (1939)' had a great influence on Professor Christopher Freeman, who is called the forerunner of science policy.
  - Since the late 1980s, the perspective of the National Innovation System - an overall system where various innovation actors in a country form a network and support corporate growth in connection with national policies. Since the OECD officially adopted it, it has served as a basic framework for science and technology innovation policies until now.
    - ▸ As social acceptability of innovation is secured and open innovation in which citizens are incorporated as actors in the innovation system is promoted, a transition is in the process to a system with a policy goal for sustainable development and improvement of people's quality of life.
  - Mission has changed from pursuit of technology and space technology development to responding to climate change and social problems, and the mutual influence and dependency among national policies have increased due to their complexity and multi-layered structure.
  - Mission-oriented innovation policy (MOIP) is a transformative innovation policy proposed by Professor Mazzucato of the UK to solve grand challenges, such as environmental pollution, energy crisis, and new infectious diseases.

Normative Requirements for MOIPs

– Professor Mazzucato presents the criteria that mission–oriented tasks must satisfy as follows.

- ▸1) Specify social values
- ▸2) Set specific goals
- ▸3) Include research and innovation
- ▸4) Collaborate between industries, actors and academics
- ▸5) The task itself should include a method for solving the problem

- ▸ A task is distinct from a goal as it is the work (responsibility) that needs to be fulfilled.
- A bottom-up communication method is needed to set specific goals (great challenges) with various actors, such as academia, industry, and civic groups, and solve multiple industry problems.
- It is necessary to approach innovation for sustainability and well-being beyond economic growth or product and process innovation.

2. Status and Issue

- Oversea trends
  - (US) Pursue technology development for specific missions in a wide range of activities with the nature of public goods, and plan and promote research with strategic significance in basic research.
    - ▸ Avoid "picking a winner only" in R&D investment and create an appropriate regulatory environment to establish an efficient market mechanism and set the direction of private investment.
    - ▸ Recognize maintaining technological supremacy and widening the gap in competition with China as a grand challenge and promote the enactment of the US Innovation and Competition Act.
  - (Germany) Set High-Tech Strategy 2025 and link industrial policy (Industry 4.0) with social difficulties.
    - ▸ Blend of Transformer missions to solve European social problems such as climate change with Accelerator missions to respond to pressing industrial, economic, and geopolitical challenges.
    - ▸ Secure competitiveness in industries such as health and disease control, mobility, safety, and security, urban and rural areas, energy, economy, and labor, and link this with social problem-solving.
  - (UK) Proceed Grand Challenges programs, such as future transportation, eco-friendly growth, AI and data, and an aging society centering on the new MOIP.
  - (Japan) Promote two versions of Moonshot and New Business Structure Vision.
    - ▸ Moonshot is a future-oriented science and technology policy that pursues challenging R&D based on bold ideas or destructive innovation based on research investment in basic fields.
    - ▸ The new business structure vision is similar to Germany's High-Tech Strategy 2025.
    - ▸ In the case of Japan, it seems that MOIP (Strategic Basic Research + Challenging R&D of Disruptive Innovation + Social Sustainability Orientation) is a mixture of the US, the UK, and German strategies.

- Domestic Situation
  - Unlike hegemons like the US and China that are technologically and industrially mature, countries, such as Germany and South Korea need to secure technological sovereignty.
  - In the post-COVID-19 era with the launch of the new government, it is necessary to set strategies and tasks to upgrade the innovation ecosystem and enhance competitiveness.
  - As the two major transformations of decarbonization and digital transformation for carbon neutrality progress, socio-technological transition management and transformational innovation policies are needed.
    - ▸ Although the Green New Deal and the Digital New Deal are being promoted, it is pointed out that the framework of the past deals with the new transformative challenges, so it is required to approach it with a new MOIP.
    - ▸ The role of S&T is demanded in various areas and tasks, including S&Tsovereignty, maintaining the gap in science and technology, enhancing industrial competitiveness , upgrading the innovation ecosystem, responding to public health and social issues, and promoting the major two transitions.

- Science and technology policy issues for mission-centered innovation policy promotion.
  - Building innovation-driven S&T governance.
    - ▸ It is necessary to establish governance from the perspective of system transformation in which scientists, economists, and users participate together in almost all socio-economic policies rather than innovation policies centered on economic growth led by scientists.
    - ▸ It needs a promotion system of public-private cooperation to set and achieve missions that put emphasis on good values in humanity and society.
  - How strategic national R&D projects are implemented.
    - ▸ It needs to consider strategic niche management* and transition management.

      * Strategic niche management is a methodology for reanalyzing technological innovation and change through a multi-level perspective as a systems approach, and for the transformation of entrenched social technology systems.
    - ▸ In other words, set the final goal of the challenging target - sustainability - and continuously and iteratively modify policy measures (solutions) towards that goa.
  - Co-production of innovation and discussion for open innovation through citizen participation.
    - ▸ Everyone in civil society should be able to be a player and participant in innovation, and this should be able to be led to efficient co-production of knowledge.
    - ▸ For Open Innovation, not only researchers but also citizens, who are users, need to be recognized as actors in the innovation system.

3. Policy Proposal

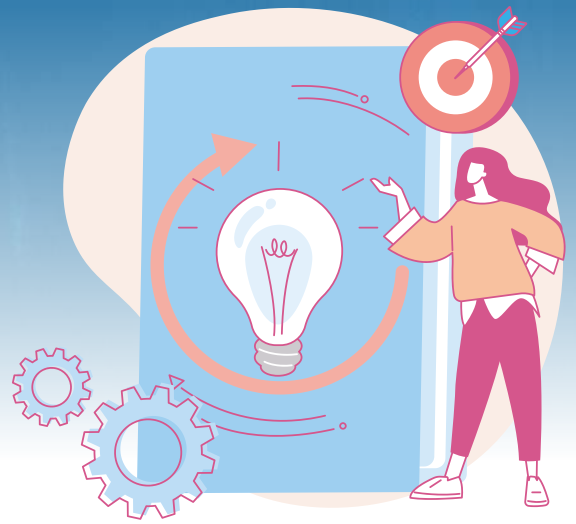
- (Governance) It is necessary to move away from a government-led industrial policy to catch up with advanced countries toward innovation-centered governance led by the public-private partnership.
  - It needs to shift from the classic single models, such as Basic Research, Applied Research, and Development, to the private-led innovation policy.
- (Mission setting) Pursue a complex mission-oriented innovation policy that mandates everything rather than grandiose and grand mission setting.
  - ▸ Traditional missions , such as space technology development, securing US-style technological sovereignty, solving Europe-style major challenges, and all other government-led industrial issues that have been dealt with so far are possible to be handled with a mission-oriented approach.
- (Promotion method) After establishing a collaboration system in various policy areas, promote bottom-up communication.
  - Considering civil society's indifference to and low participation in science, technology, and innovation policies, it is necessary to prioritize preparing a system for cooperation in various policy areas rather than an unconditional bottom-up method participated by citizens as in Europe.
    - ▸ After establishing a cooperative system, progressively promote bottom-up policies in the future.
    - ▸ There is an experience in overcoming a crisis in the past by operating a cross-departmental collaboration system.
  - MOIP is not grandiose or tremendous, but a change in the way of working.
- (Secure technology sovereignty) Need to secure technological sovereignty and maintain the technology gap.
  - Securing technological sovereignty is one of the biggest challenges in Korea's mission-oriented innovation policy.
    - ▸ Identification of core technologies, maintenance of core technologies, and GVC inspection shall be set as missions, and technological sovereignty linked to the value chain needs to be checked.
    - ▸ However, it should be careful not to misunderstand that technological sovereignty requires self-sufficiency in all technologies or focuses on technology security.

- (Securing strategic technology) Need to secure the latest strategic technology through benchmarking such as US C&ET*

  * Critical & Emerging Technologies (C&ET)
  - Currently, various organizations are selecting promising and strategic technologies, but efforts are needed to secure the latest strategic technologies through benchmarking in that they are not in focus.
    - ▸ The scope of strategic technology is expanded as the US sets core technology as part of a strategy by semiconductor regulation.
    - ▸ In the case of C&ET, the goal of becoming a global leader is continuously set and pursued through joint technical cooperation with allies and partner countries.
    - ▸ It needs to put emphasis on C&ET development and innovation through private sector efforts using market mechanisms rather than direct support from the government budget.
  - Even in leading technology fields, such as semiconductors, the government needs to set missions and provide continuous support through science and technology policies to maintain the technological gap.
- (Response to huge social challenges) Research planning and promotion through induction of citizen participation
  - It is necessary to respond to various social and technological complex challenges, such as decarbonization, digital transformation, aging society, the advent of AI, and mobility change.
    - ▸ However, given that responding to significant challenges has a tremendous social impact, it is necessary to build a related system in which citizens can participate.
- (Application to traditional missions) Apply mission-oriented innovation policy approach to general mission performance and improve policy promotion system and administrative system into a mission-specific performance system.

R&D Paradigm Shift Plan for Innovative Growth led by the Private Sector

Summarized by KISTEP from 147th KISTEP Wednesday Forum



1. Discussion background

- The Wednesday Forum is held regularly to analyze the current status of various science and technology fields, diagnose problems, and seek countermeasures. The 147th forum will discuss R&D paradigm shift plan for innovative growth led by the private sector.
- The new government presents a "dynamic economy led by the private sector and pushed by the government" as one of the national goals to create the next growth engine.
  - It needs to shift the center of the economy to "businesses" and "people", aiming for an economic system in which growth and welfare go through a fair virtuous cycle amid the private sector's creativity, dynamism, and vitality.
- In science and technology, innovation will gain vitality as private requirements are incorporated in line with national goals, and the government sets out national tasks to provide assistance.

  - Strengthen mission-oriented R&D and promote the transition to market-oriented industrial technology R&D to improve the quality of R&D.
  - Establish the「Public-Private Science and Technology Innovation Committee」to activate public-private cooperation, such as the establishment of a permanent cooperation channel between the technical and industry-specific consultative bodies and relevant ministries.
  - Strengthen private S&T capabilities through tax support and the introduction of various R&D support methods for private R&D.
  - Present various government tasks, including innovation of the entire process of regulatory administration using big data and AI technology and introduction of negative regulatory systems for major new industries through regulatory sandbox plus+.
- The carbon-neutral R&D field requires an extended period, huge costs, and great risks due to delays in technology development, but it is essential to secure future industrial competitiveness.
  - In particular, steel has the highest greenhouse gas emissions among the industrial sectors. It accounts for 17% of the total national greenhouse gas emissions, so it is necessary to actively solve problems using the private sector's capabilities.
  - National R&D projects and government systems need to be aligned with consideration of the limitations of individual companies' capabilities and the rapidly changing future industrial systems.
- The government has been striving to establish a system that can take responsibility for lifecycle of R&D, from implementation and demonstration to application, to secure innovative technologies through carbon-neutral R&D.
  - For carbon neutral R&D, a special carbon neutral technology committee was established under the「National Science and Technology Advisory Council」, to set climate science R&D measures for carbon neutrality and climate crisis response and a region-specific carbon neutrality promotion strategy.
  - 2022 is the first year to promote full-scale carbon neutrality. Establishing a full-fledged cooperation system is under progress, including enacting and promulgating an enforcement decree and operating a working-level consultative body in line with the implementation of the Basic Law on Carbon Neutrality (March 25).
  - Achieving carbon neutrality requires the government's strong will and large-scale financial support and the development of leading technologies led by the consumer - the private sector.

2. Status and Issue

- R&D Status of the Steel Industry
  - Major steel importers are stepping up government fiscal funds based on carbon pricing, ESG-responsible investment, and green classification standards.
    - ▸ Japan will develop blast furnace CO_2 reduction technology by 2030 and hydrogen reduction submission technology by 2040 before their gradual introduction.
    - ▸ Europe has been pursuing hydrogen reduction steelmaking technologies since 2017 and delivering fossil-free steel to Volvo in 2022.
    - ▸ China prioritizes the manufacture of blast furnaces/hydrogen reduction steelmaking using hydrous gas and will introduce European facilities with hydrogen reduction steelmaking technologies in the future.
    - ▸ Korea plans to promote full-scale R&D using the basic technologies of private companies, and will gradually transition to hydrogen reduction in 2030.
- Transform the planning and evaluation of national R&D projects into the market-led system.
  - The commercialization task demands shifting focus to effectiveness and efficiency rather than an evaluation system emphasizing procedural suitability.
    - ▸ Transform key evaluation indicators into 'technology transferred to companies' and actively encourage the participation of leading companies by industry.
    - ▸ Optimize the time and resources invested in project planning and selection, and enhance practical corporate technology transfer through performance management.
- When selecting tasks, it is necessary to avoid promoting stable tasks with a high success rate and to choose innovative tasks by supplementing the expertise of evaluators.
    - ▸ It tends to select projects with a high probability of success from the concern that R&D should not fail.
    - ▸ It is necessary to use experts with a relatively high understanding of industrial field technology to select tasks with high ripple effects.
    - ▸ The evaluation run by the committee unit that causes weakening individual accountability for selecting tasks and avoiding major decisions on tasks should be resolved.
- Need for efficient project management through improvement of national R&D system and administrative procedures.
  - Support establishing a platform to secure management flexibility through full-scale innovation of the operating system for national R&D projects and to raise the dynamics of the industrial ecosystem among large enterprises and SMEs.
    - ▸ It needs support to simplify research management, including a preliminary feasibility study for optimal response to rapid changes in technology and environment.
    - ▸ Due to the evaluation and agreement process, the task period is practically insufficient, so it is necessary to prepare a management framework for each field and market condition.
- Necessary to review commercialization from the planning stage to catch up with the diversity and speed of change in industrial demand.
    - ▸ Demand for industrial technology is mostly raised by universities and government-funded research institutes, but in order for research results to be commercialized, it is necessary to resolve the gap between technology development and commercialization.
- Need to alleviate unnecessary administrative work due to frequent changes of a person in charge of the task management agency and lack of expertise.
    - ▸ Systematic support is insufficient due to the excessive work of the person in charge of the management agency for simple system operation support and the lack of professionalism of experts (PD, PM) in each field.
- Need to expand the researcher's authority due to the lack of autonomy for the research manager to manage the lifecycle of the R&D process.
    - ▸ It is difficult to manage moving target-type research goals and autonomously adjust the participating institutions due to the limited authority of the general manager.
    - ▸ It is necessary to solve the problem of increased purchase and installation periods due to strengthened safety standards of private companies and the global purchasing system.
- Need to redefine the government's role in national R&D projects.
  - Need to shift national R&D projects to the perspective of "enhancement of national welfare" through innovative and creative research.
    - ▸ The government needs to fully support R&D expenses in the early stages of technology development, and after technology development is complete, it needs to have the plan to recover the cost by generating revenues from sales and overseas technology sales.
    - ▸ A successful task is a technology developed which can be transferred to the industrial field. It is also necessary to develop a technology that shows performance information (track record) through technical cooperation between small and medium-sized venture companies and large companies.

- Need to supplement the lack of leading technology development at the national level by avoiding support for large corporations and reducing the scale of support due to political considerations.
  - ▸ In the case of collaboration tasks between companies, it is necessary to solve the problem of specifying tasks of the same or similar size as competitors for reasons of fairness.

3. Policy Proposal

- Encourage the private sector to participate in national R&D.
  - Required to design projects and establish policies so that government R&D investment can reflect the R&D needs of the industry.
    - ▸ The government needs to actively support the construction of large-scale infrastructure and facilities which companies cannot invest in considering their profits.
  - To promote active participation of the private sector, it is necessary to promote tax support for large-scale investment conversion rather than comprehensive tax credits.
    - ▸ Expand tax support for depreciation due to the replacement of existing facilities along with simple tax support.
    - ▸ Complement the lack of effectiveness of R&D resources for corporate support and maximize the performance through linkage of tax, social and regulatory policies.
- Establish a platform for connection and collaboration to secure the dynamics of the industrial ecosystem.
  - Support for establishing a platform to secure institutional flexibility through full-scale innovation of the national R&D task operation system and secure the dynamics of the industrial ecosystem among large, medium-sized and small businesses.
    - ▸ Improve the R&D program system and simplify administrative procedures for an optimized approach to rapid changes in technology and environment.
  - Enhance policy reliability through inter-ministerial cooperation and close cooperation between science and technology policies and industrial economy policies.
- Prevention of neglected fields and granting of autonomy to researchers according to top-down planning.

  - Recently, non-designated competitions and free contests are on the rise, and additional voluntary competitions will be expanded at the beginning stage of the program in the future.
  - In addition to the flexibility of planning, the flexibility to modify the project goal according to the circumstances should be considered.
- Maintain an appropriate proportion between basic and application/development, short-term and long-term tasks.
  - Consider maintaining the proportion of existing investments as basic fields may be neglected while pursuing commercialization results.
  - Investing funds for short-term performance in a specific sector and strategically allocating resources for long-term investments.
    - ▸ Perform an in-depth review of whether R&D performance is linked to innovative growth and performance analysis from a mid-to-long-term perspective.
- Promote social consensus on issues of private sector-led innovation policy.
  - Since government R&D is carried out with taxpayers' money, governance by subject should be established for organic cooperation, including large corporations.
    - ▸ The role should be set so that government R&D investment can serve as an assistant for the private sector and contribute to the qualitative improvement of research results of government-funded research institutes and universities.
  - It is necessary to establish the role of large corporations to increase social trust in large corporations and to provide education and training functions and roles to large corporations to nurture industrial human resources on a global level.

Direction of National S&T Diplomacy in the Era of Technological Hegemony

Summarized by KISTEP from 143rd KISTEP Wednesday Forum

1. Background

- Wednesday Forum seeks solutions to issues in diverse Science and Technology fields by analyzing the current status and diagnosing problems. The discussion has taken place under the theme of "Direction of National S&T Diplomacy in the era of Technological Hegemony".
- As China has emerged rapidly with advanced technologies, it poses a threat to the US-led multilateral western order. The US stresses that China's rise poses a significant challenge to the free world order.
  - The national security strategy, the national defense strategy, and the congressional report of the US all recognize the emergence of China's technology as a critical threat to the US hegemony and security.

※ The House Armed Services Committee's Future of Defense Task Force advocated for US's dominance in AI in November 2020. It stressed that the US must secure a dominant position in AI, emulating the Manhattan Project.

- The world sees the technological revolution and the changing world order concurrently, and cutting-edge technology is a crucial battlefield for hegemony.
  - US-China competition for technological hegemony led to the tech cold war and digital cold war, raising concerns over the decoupling and polarization of the global economy.
- US-China competition over hegemony is not confined to geology, politics, and the military. Bilateral rivalry spreads to digital technology, such as AI, Semiconductors, and 5G.
  - Digital economy and emerging technology are regarded as strategic assets in the competition of great powers. Technological competition has spread to geopolitics, security, and ideology spheres.
- The Guardian's survey of 12 European countries in September 2021 shows 62% of the respondents project that the era of a new cold war is progressing, centering around the US and China, and is likely to prolong.
  - Securing a dominant state-of-the-art technology power is key to our future leadership. Competition and decoupling in sophisticated technology fields are expected to expand limitedly but continue.
  - US-China competition over hegemony is significantly affecting not only them but also the global economy and security. The world is contemplating a survival strategy to minimize economic losses and the pressure of picking a side with either the US or China.
- Amid the hegemony struggle, countries worldwide are not picking a side but are taking a practical approach to maximizing national interests by diversifying diplomatic channels and supply chains, considering numerous factors, such as technological capabilities, economy, and diplomacy.
- Korea is the only remaining divided country on the planet. It would be hard for Korea to steer clear of a potential physical confrontation between the US and China.
  - Korea's export of intermediate goods takes up 70% of the total export. And it is closely related to China in the supply chain of many sectors. Therefore, the US' decoupling of the supply chain with China will hugely impact the Korean economy.
- As the US and China can become friends or foes, Korea must play a diplomatic role and responsibility, befitting its high standing amid the complicated global order.
  - It is necessary for Korea to make efforts to make technology innovations to respond to US-China competition over technological hegemony and lead the global order in the future. Also Korea needs to achieve independence and self-reliance of S&T through multilateral S&T diplomacy with Europe, Japan and Australia to prevent core technologies from leaking.

2. The current status and issues

• Global trends

- As nationalism and economic bloc spread for the sake of respective national interests, the global supply chain is reshaping, and competition for advanced technology is accelerating.

▸ Countries around the world are focusing on technology innovations and industrial sophistication to lead the future digital era by announcing strategies, such as 'Made in China 2025,' 'United States Innovation and Competition Act' and 'Germany's Industrial Strategy 2030'.

- Full-blown digital competition between China and Western countries.

▸ China strives to solidify its global leadership in cutting-edge technology sectors with the Digital Silk Road and One Belt, One Road Alliance of International Science Organizations (ANSO).

▸ The Western countries and the US respond to a rising China with a US-led technology alliance through the G7 summit's Build Back Better for the World (B3W) and the EU's Digital for Development (D4D).

▸ The US earnestly provides digital support to Africa and Central and Latin America. Recently, it has engaged in a more multilateral approach in response to the emergence of China through the Indo-Pacific Economic Framework (IPEF).

- The US strives to lead anti-China alliances through Quad, AUKUS, and IPEF and decouple the US and China, centering around state-of-the-art technologies.

▸ The 116th US congress passed the Innovation and Competition Act in the Senate in 2021 and America Competes Act in the House in 2022. It is dubbed "AI congress" as it focuses on AI at a level never seen in the history of the congress.

▸ Under the innovation and Competition Act, the US invests KRW 298 trillion in new emerging technologies. With America Competes Act, the US supports KRW 61 trillion in semiconductors and KRW 190.7 trillion in S&T innovations.

- China is striving to become self-reliant in response to the restructuring of the supply chain, excluding China, and to reduce its dependency on external markets through a virtuous cycle aiming to expand the domestic market.

▸ China has recognized itself as the only country that can compete for innovations with the US. It emphasized "innovation-leading country" and "self-reliance of S&T" in the 14th Five-year-plan. It also aims to become the world-best country through S&T innovations.

- Germany, Australia, Japan, and the EU maintain an alliance with the US based on high technology prowess and seek to reduce external dependency with technological innovations and the diversification of the supply chain for economic security and stronger technological sovereignty.

▸ These countries actively engage in small multilateral cooperations, such as Japan-Europe cooperation, EU-level cooperation in Europe, and Australia's Quad and AUKUS.

▸ Japan has instituted the Ministry of Economic Security to minimize the repercussions of US-China competition over technological hegemony while developing technologies.

▸ Australia is a member of Five Eyes, an intelligence alliance, and Quad. It seeks to diversify diplomatic channels with technology innovations in technological cooperation with western countries, including the US, and Smart City Development Cooperation with ASEAN.

▸ EU joins the move to contain the spread of China's influence by building the Indo-Pacific Cooperation Strategy focusing on a supply chain and digital transformation.

- Reshaping the global order centering around small-scale cooperative bodies between allies by issue and region

▸ Digital Economy Partnership Agreement (DEPA, in June 2020), AUKUS, a defense alliance between Australia, the UK, and the US and Quad.

▸ At East Asia Summit in October 2021, US President Biden proposed the "Indo-Pacific Economic Framework" with a vision for comprehensive economic cooperation.

• Domestic status

- Last year, Korea established Foreign Economy and Security Strategy Meeting and Presidential Secretary for Cyber Security to reorganize a pan-government response system for technology hegemony.

- Considering strategic values like a supply chain and national security, Korea has designated 10 sectors of National Strategic Technology essential to obtaining technological hegemony. Korea is poised to enact special laws.

- Through the ROK-US Summit held in May 2021 and following ministerial-level meetings in December 2021, Korea strengthens Korea-US technological alliance by securing capabilities in emerging technologies and expanding cooperation substantially.

3. Policy Recommendations

- Korea must set up ambitious mid-and long-term strategies based on analysis of challenges and opportunities arising from US-China competition over technological hegemony and understanding global trends.

- A race for technological hegemony takes a complicated competition structure of "Technology-security-value". Therefore Korea must exert efforts in technology security and diplomacy to become a global leader in the future.

  - To establish a comprehensive mid-and long-term vision with the Korean version of the Innovation and Competition Act encompassing innovation and solidarity.

    ▸ To develop a comprehensive strategy to strengthen national competitiveness and international standing in the future, including policy and financial support to lead emerging technologies, more robust technological security and economic security, and strategies for global solidarity and engagement.

  - To develop Korea's diplomacy strategies befitting the era of US-China confrontation over technological hegemony and Digital Economy at a comprehensive national strategy level and implement S&T diplomacy with a mid-and long-term roadmap.

  - To legislate and build governance to strengthen open technological sovereignty and technological security for strategic autonomy and initiative.

- To reorganize a system to implement Korea's S&T diplomacy by studying S&T diplomacy cases of major countries and create opportunities to cooperate with technologically advanced countries through a working-level centered and pan-government standing consultative body.

  - To broaden the participation of the Korea-US S&T Joint Committee Meeting from an inter-government consultative body to a comprehensive consultative body encompassing public and private (including companies and academia).

  - To strengthen S&T cooperation with the EU by hosting the Vice Ministerial-level 7th Republic of Korea-EU Joint S&T Cooperation Committee and 2nd Korea-EU High-Level ICT Policy Dialogue in 2022.

  - EU aspires to forge a digital partnership with Korea. The negotiation will continue in-depth through a working-level discussion in the future.

- To support joint research with prestigious researchers and a researcher exchange program with research institutes in national strategic technology fields.

  - To develop human resources to strengthen the capabilities of S&T diplomacy and tap into experts by creating an environment for public-private-academia communication and cooperation.

    ▸ To pursue substantial cooperation through joint research and forum in emerging technology fields agreed upon by Korea and the US, including Quantum, Bio, and semiconductors, and constantly expand the cooperation scope.

    ▸ To acquire advanced technology through exchanges of information and research between domestic and foreign human resources in core technology fields, such as AI, and create a new BrainLink to facilitate the establishment of a global network.

- To diversify S&T diplomacy by building and expanding the foundation for cooperation with leading countries with advanced technology, forming and cooperating with technology leaders like the EU, and strengthening digital diplomacy with developing countries like those in South East Asia, Africa, and Central and Latine America.

  - To consider creating Korea-US International Technolgy Cooperation Fund (TBD) to cooperate in emerging technology fields in a stable and sustainable manner.

  - To negotiate to become a quasi-member of Horizon Europe, the EU's funding program for R&D with a budget of EUR 95.5 billion, or KRW 12.9 trillion, from 2021 to 2027 to diversify S&T cooperation network.

KISTEP News

The Opening Ceremony of the IRIS(Integrated Research Information System)

KISTEP (President Sang-seon Kim) has joined hands with industry, academia, and research institutes to discover new national growth engines and strengthen R&D competitiveness.

KISTEP held a business agreement ceremony with KIRD (the National Institute of Science and Technology Development), Dankook University, and CIAST (Chungcheongnam-do Science and Technology Promotion Agency) at Dankook University Cheonan Campus on October 8th (Friday).

Through the agreement, the four organizations plan to contribute to Korea's science and technology innovation by training human resources and discovering new growth engines based on R&D cooperation and exchange in the science and technology field. To this end, they promised to research and study R&D policies for ▲ national science and technology innovation, discover new national growth engines and strengthen R&D competitiveness, ▲ cultivate HR exchanges and career development, ▲ share information on latest technologies and trends, and ▲ cooperate where needed additionally.

This agreement is of great significance in that it is cooperation between significant institutes in the field of science and technology.

A B

A | Gyung-su Lee, Vice Minister for Science, Technology and Innovation
B | Byung-seon Jeong, President of KISTEP

A B

A | IRIS demonstration
B | Commemorative photo

Gyung-su Lee, Vice Minister for Science, Technology and Innovation, presidents of five institutes*, the head of Korea Medical Device Development Fund, and KISTEP President Byung-seon Jeong attended the opening ceremony.

The opening ceremony was held in the following order: ▲Declaration of the opening of Vice Minister Gyung-su Lee, ▲IRIS demonstration, ▲presentations from participating organizations, and ▲IRIS-related announcement by KISTEP President Byung-seon Jeong.

* National Research Foundation of Korea, Korea Evaluation Institute of Industrial Technology, Institute for Information & Communication Technology Planning & Evaluation, Korea Technology and Information Promotion Agency for SMEs, Korea Agency for Infrastructure Technology Advancement.

The IRIS opening ceremony is held to announce that IRIS, an integrated research support system for all ministries that is organically linked with three sub-systems (research fund management, researcher information, and project management), has completed its preparations and will be officially launched.

When IRIS is applied to the research field, researchers can perform all research administration tasks with a single log-in (www.iris.go.kr), and ministries and specialized institutions can prevent similar/duplicate research and plan collaborative research. In addition, it is expected that the regulation reforms will be ly applied to the research field through IRIS, increasing the efficiency of research administration.

IRIS is an integrated system established in cooperation with related ministries and institutes and has been promoted as a cross-ministerial project since June 2017 as part of the 'researcher-centered R&D management system innovation', a national task of the Moon Jae-in government. IRIS aims to resolve the inconvenience of research administration due to the difference in research project management regulations and systems for each ministry and institute.

2023 National R&D Investment Direction Online Public Hearing

The '2023 National R&D Investment Direction and Standards Online Public Hearing' hosted by the Ministry of Science and ICT (hereinafter referred to as the Ministry of Science and ICT) and supervised by the Korea Institute of Science and Technology Planning and Evaluation (KISTEP) will be held through an online channel on Wednesday, February 23rd.

This public hearing was prepared to explain the 'National R&D investment direction and standards (draft) for 2023' and to freely communicate and collect opinions for industry-university-research experts, government officials and the general public.
※ To prevent the spread of COVID-19, it is broadcast live on Naver TV, YouTube, and Kakao TV.

The first part of the public hearing started with a general presentation of the '2023 investment direction (draft)' by Oh Dae-hyeon, head of the research budget. Next, a panel discussion consisting of experts from the industry, academia, and research institutes, followed by a question-and-answer session, was held by Professor Shin-Doo Lee of the Department of Electrical and Computer Engineering at Seoul National University (Director of the R&D Investment Innovation Planning Division presided over by the Innovation Headquarters of the Ministry of Science and ICT) as the chair.

The 9 key investment directions in the 4 areas presented in the general presentation are △Strengthening future growth potential ((1) strengthening creative and challenging basic research and expanding future scientific and technological talents, (2) laying the foundation for systematic nurturing of national essential strategic technologies , (3) strengthening the material/parts/equipment ecosystem and supporting creation of future supply chains), △ Improving the quality of life of the people ((4) strengthening the ability to respond to infectious diseases and supporting the bio-health sector, (5) mission-focused to solve social problems Reinforcement of type R&D, △ Leading the era of great transformation ((6) Promotion of digital transformation in all areas through DNA advancement, (7) Leading 2050 carbon neutrality through technological innovation and creation of an innovative ecosystem) △ Expansion of inclusive innovation capabilities ((8) Creation of a self-reliant innovation base to enhance the vitality of the region, (9) promotion of start-ups and commercialization based on excellent research results, and fostering of promising small and medium-sized enterprises).

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A | Lee Kyung-soo, head of the Science and Technology Innovation Division

B | Jeong Byung-seon, president of KISTEP

The second part of the public hearing was followed by an announcement of detailed investment directions for each of the six technology fields consisting of public space, energy environment, mechanical materials, ICT convergence, life and medical science, and basic infrastructure, and in-depth discussions by expert committees.

At this meeting, Lee Kyung-soo, head of the Science and Technology Innovation Division, said, "In order to effectively respond to global technological hegemony, digital transformation, 2050 carbon neutrality, and population aging within the limited government R&D budget structure, strategic investment in government R&D is necessary. " He also asked, "I hope that good suggestions and opinions will be presented through the public hearing so that the direction of national R&D investment can meet the vivid voices of the field".

Jeong Byung-seon, president of KISTEP, said, "The philosophy of the national R&D investment direction and standard (draft) for 2023 is to respond to technological hegemony, secure global science and technology leadership, leap forward as an innovative powerhouse leading the technology economy, and realize an inclusive society where all people are happy". In addition, he said, "As Korea aims to become a leading country beyond advanced countries, we will continue to make efforts to establish a leading science and technology investment and R&D investment system that turns a crisis into an opportunity".

KISTEP received a Government Award at '2022 Science and ICT Day Commemoration Ceremony'

'The 2022 Science and ICT Day Commemoration Ceremony' was held on April 21 (Thursday) at the International Conference Center of the Korea Science and Technology Center under the theme of 'Challenges for the future and innovation, science and technology/ICT with the people'.

Prime Minister, Kim Bu-gyeom, Minister of Science and ICT, Lim Hye-suk, Chairman of Korea Communications Commission, Han Sang-hyeok, President of Korean Federation of Science and Technology Organizations, Lee Woo-il, and President of Korea Federation of ICT Organization, Roh Jun-hyung attended the event and awarded government awards to 162 people of merit in science technology and information communication promotion and national R&D performance evaluation.

Byun Sun-cheon, Director General of Office of S&T Policy Planning at KISTEP, received the Science and Technology Medal and Hwang Ji-ho, Director of the Strategic Planning Center received the President's Commendation for their contribution to science and technology promotion.

In addition, President Jeong Byung-seon was awarded the Prime Minister's Commendation for his contribution to national R&D performance evaluation (research institute).

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A | Kang moon-sang, Director of the General Affairs & Computer Office and Jeong Byung-seon, President of KISTEP

B | Byun Sun-cheon, Director General of Office of S&T Policy Planning

C | Hwang Ji-ho, Director of the Strategic Planning Center

KISTEP held the 17th Trilateral S&T Policy Seminar

KISTEP held the 17th Trilateral S&T Policy Seminar as an online/offline meeting from October 31st(Mon) to November 1st(Tue).

The Trilateral S&T Policy Seminar has been held annually since its launch in 2006 to discuss current issues of S&T policy, research highlights of institutes, and promote cooperation among the five institutes in Korea, China, and Japan. The participating institutes include KISTEP, STEPI (Science and Technology Policy Institute), CASISD (Chinese Academy of Sciences Institutes of Science and Development), CASTED (Chinese Academy of Science and Technology for Development), and NISTEP (National Institute of Science and Technology Policy).

Under the theme of "Digital Transformation", this seminar was held in five sessions: △2022 Highlights of Research Activities, △Thinking Beyond Digital Transformation: Digital Divide and Social Impacts, △Digital Transformation and the Future of Work, △Data-driven STI Policy Design and Implementation, △Post-COVID-19 Digital Transformation: Challenges and Future Strategies.

President Byung-Seon Jeong said, "The Trilateral S&T Policy Seminar has firmly established itself as a platform for knowledge exchange and cooperation in which major S&T policy research institutes from the three countries gather to discuss common problems and to seek out the roles and solutions of S&T policies". He said, "Through this seminar, we found common interest topics such as nurturing future talents and establishing data-based STI policies. We look forward to promoting close collaboration between institutes including joint research projects, researcher exchanges, and case studies".

Next year, the 18th Trilateral S&T Policy Seminar will be held in China, hosted by CASTED.

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A | Commemorative Photo

B | Presenting by Byung-Seon Jeong, President of KISTEP

C | Presenting by Byung-Seon Jeong, President of KISTEP

2022 Science and Technology Diplomacy Forum

The 2022 Science and Technology Diplomacy Forum, hosted by the Ministry of Science and ICT(Minister Jong Ho Lee) and organized by KISTEP, was held on December 1. This forum aimed to discuss S&T diplomacy strategies that Korea should take amidst the global technological hegemony competition.

The program was hosted by Dr. Jinha Kim, Director of the Center for International Cooperation Policy at KISTEP starting with the opening remarks of ▲ Tae Seog Oh, 1st Vice Minister of MSIT, and the congratulatory speech of ▲ Sangmin Lee, Member of the National Assembly, congratulatory speech by Hyangja Yang (Member of the National Assembly), and welcoming remarks by ▲ Byung-Seon Jeong, President of KISTEP. There were two presentations by ▲ J. James Kim, Chief of the Center for Regional Studies, Asan Institute for Policy Studies, and by Jun Lee, Director General of the Center for Industrial Policy Research, KIET. After presentations, panel discussions were held and ended with online/offline Q&A sessions.

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A | Congratulatory Speech by Sangmin Lee, a Member of the National Assembly

B | Congratulatory Speech by Hyangja Yang, a Member of the National Assembly

Opening Speech by Tae Seog Oh, 1st Vice Minister of MSIT

The 1st Vice Minister of MSIT, Tae Seog Oh, stated in his opening remarks: "We are seeking for a variety of R&D and HR development strategies to advance the 12 strategic technologies we need on a national level. It is crucial to strategically broaden the scope of science and technology through S&T diplomacy and international cooperation", highlighting the importance of the forum.

In a following congratulatory speech, Sangmin Lee, a member of the national assembly stated, "We hope that this forum will play a significant role in S&T diplomacy and that the National

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A | Welcome Speech by Byung-Seon Jeong, President of KISTEP

B | Presenting by J. James Kim, Center Chief, Center for Regional Studies, Asan Institute for Policy Studies

Assembly will also widen its horizons to achieve global leadership". Hyangja Yang, a member of the National Assembly, stated, "Science has no borders because it is the product of humanity, but technology has borders because it is a matter of the state", adding, "I hope this forum will be a place to seek collaborative solutions and strategies to win the global competition, and I pledge to support it with policies and legislation".

In his welcoming remarks, Byung-Seon Jeong, president of KISTEP, stated, "In the past, pursuing the truth through observation and experimentation was the realm of science, and resolving disputes between sovereign nations through cooperation was the realm of diplomacy. However, today, 'technology' is the realm of conflict and also the solution". Then, he stressed the importance of S&T diplomacy forum stating, "In this regard, it is time for collaboration and cooperation between the two fields".

In the presentation, 'Challenges and Tasks: Implications of US High-tech Regulations and Policies,' J. James Kim, Center Chief, Center for Regional Studies, Asan Institute for Policy Studies, discussed the US technological regulation and policy trends by analyzing the background and cause of the US-China hegemony competition. He also discussed the implications of the future G2 policy stance for Korea.

Center Chief Kim emphasized that the reason for the hegemonic race is intricately intertwined with multiple domains, such as politics, economy, society, and diplomacy, and stated that a multifaceted approach should be made in response. In addition, he noted that "the US policy position appears geared to acquire an advantage in the great power struggle with China by safeguarding the economy and developing technologies" and offered a pessimistic assessment of the future of US-China ties.

Kim emphasized, "Rather than viewing this circumstance as a challenge, Korea must find a method to 'translate' it into an 'opportunity' through internal cooperation between the government and corporations and external cooperation with the US government and corporations".

Director General of the Center for Industrial Policy Research at the Korea Institute of Industrial Economics & Trade (KIET), Jun Lee, gave a presentation titled 'Future Strategic Program, Economic Security, and the Road to S&T Diplomacy' in which he stated that the current era is characterized by unrestricted competition for industrial policies led by the United States. He analyzed the trends of semiconductor and battery industries and proposed the future direction of S&T diplomacy.

Director General Lee stressed that "the semiconductor strategy is currently critical". He indicated that the structure of the semiconductor industry is on the brink of significant changes by US intervention. However, he diagnosed the situation in Korea as, "Rather, the structure itself is rocked, and the memory semiconductor field is at stake, but the system semiconductor market is opening up opportunity".

"We are being forced to make strategic choices in various fields such as semiconductors and batteries", he suggested, "We need active diplomacy to respond to supply chain issues and reorganization that are difficult to solve on our own". In particular, Lee urged the government to push forward complex and strategic S&T diplomacies for advanced technologies.

▲ Dr. Suk-in Chang, a Senior Research Fellow at Taejae Academy, led the panel discussion and Q&A session with the participation of ▲ Prof. Sung-Hoon Park, Professor at Korea University Graduate School of International Studies (GSIS), ▲ Prof. Eun-Young Nam, Professor of the Department of Global Trade at Dongguk University, ▲ Gyu-Pan Kim, Senior Research Fellow of Japan and East Asia Team at the Korea Institute for International Economic Policy (KIEP), ▲ Prof. Seok Joon Kwon, Professor of the School of Chemical Engineering at Sungkyunkwan University (SKKU), ▲ Hyeonkyu Lee, PM of AI·Data at the Institute of Information & Communications Technology Planning & Evaluation(IITP), and ▲ Heoung-Yeol Kim, Associate Director of Biotech Policy Research Center at Korea Research Institute of Bioscience & Biotechnology (KRIBB).

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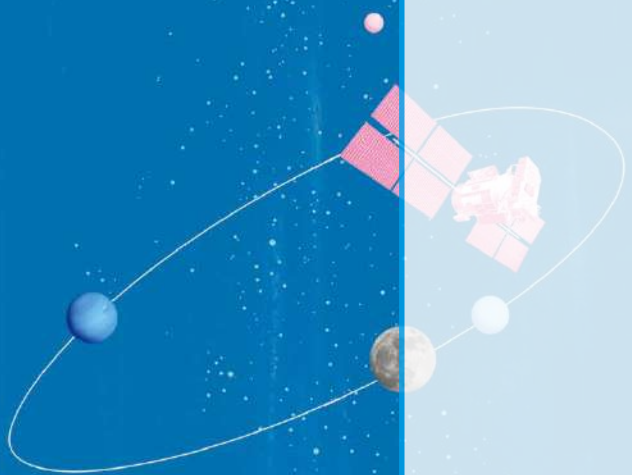
A | Presenting by Jun Lee, Director General, Center for Industrial Policy Research, KIET

B | Panel Discussion

KISTEP R&D and Beyond 2022



R&D Infographic

Results of the 2021 Composite Science Technology Innovation Index (COSTII)

● Kim,Sun-kyung, Center for Data Analysis Innovation, Research Fellow, KISTEP
● Kim Yong-Hee, Research Fellow/Director, Center for Data Analysis Innovation, KISTEP

In the knowledge-based economy, it is essential to accurately assess where Korea's STI competency stands to boost STI competency, a source of national competitiveness. With that in mind, KISTEP has conducted the 2021 COSTII assessed strengths and weaknesses of the National STI Competency along with the Ministry of Science and ICT to propose a policy direction and provide basic materials that will be used for the national policies domestically and internationally. Some indicators have been modified to enhance data availability and accuracy, and the subject countries have been expanded to include 36 OECD countries for assessment. Following are the highlights of our evaluation.

COSTII by country

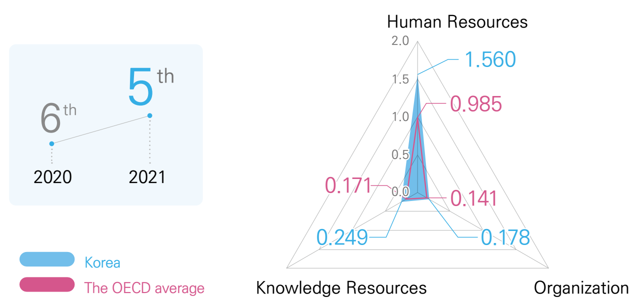
Among 36 OECD countries, Korea's COSTII was 12.658, ranking 5th, which rose by three places. It has shown that its innovation capabilities were 66.3% of the top country, the US(100).

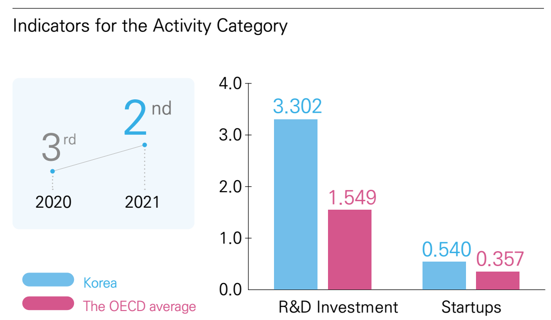
Top 5 countries	
1st USA	19.081
2nd Switzerland	15.371
3rd Netherlands	13.897
4th Germany	12.763
5th Korea	12.658

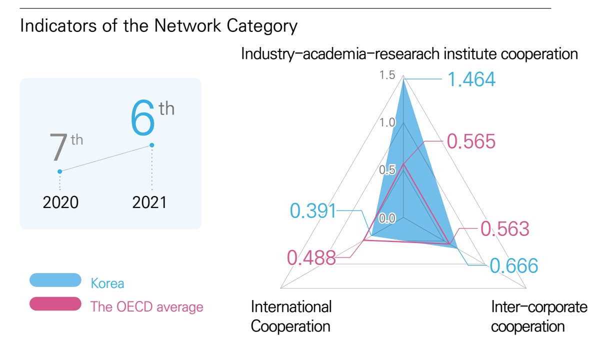
Bottom 5 countries	
32th Greece	5.144
33th Poland	4.790
34th Turkey	3.980
35th Slovakia	3.884
36th Mexico	3.745

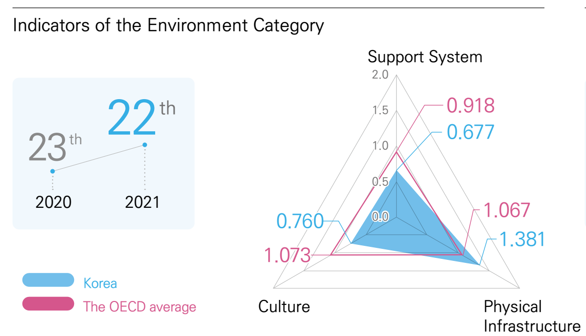
Ranking of respective categories of Korea in COSTII

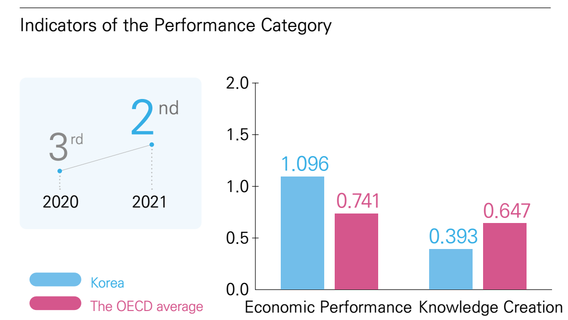
Among the fields in Korea, the resource category ranked 5th, the activity category ranked 2nd, and the network category ranked 6th. However, the environment category ranked 22nd, indicating a wide gap between categories.











Ranking of subcategories of Korea in COSTII

As for Korea, the R&D investment subcategory (2nd place) and Industry-academic-research institute cooperation (2nd place) were at the top, but the support system in the environment (30th), Culture (26th), and Knowledge creation(25th) were at the bottom.

	Category		Korea's ranking	Top countr
Top Ranking	Activity	R&D Investment	2	US
		Startups	6	Chile
	Network	ndustry-academia-research institute cooperation	2	Belgium
Bottom Ranking	Environment	Support System	30	Luxemburg
		Culture	26	Netherland
	Performance	Knowledge Creation	25	Japan

Status of the National Research and Development Programs in 2021

● Ahn Jihye, Associate Research Fellow, Center for Data Analysis Innovation, Office of National R&D Evaluation and Analysis, KISTEP

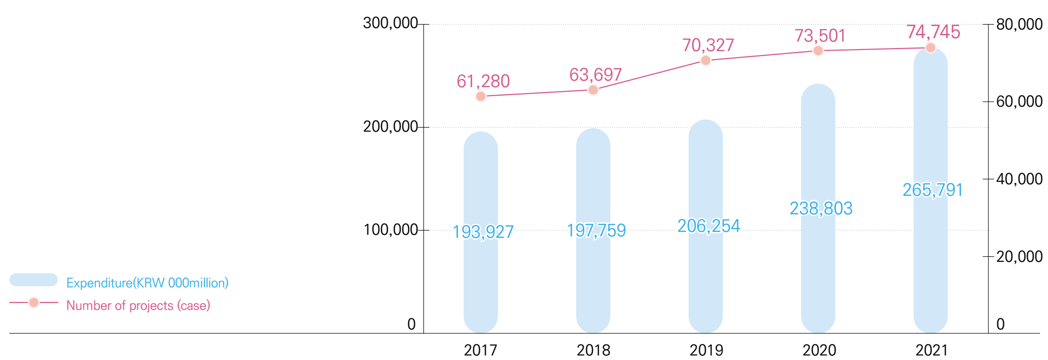
- The Ministry of Science and ICT and Korea Institute of Science and Technology Evaluation and Planning study the implementation status of the national R&D programs each year to extract analysis data from diverse perspectives and release 'the report on the investigation and analysis of the National Research and Development Programs 2021.'
- The study targets 1,181 detailed programs and 74,745 projects executed by 37 Ministries, Services, and Committees. It serves as fundamental data to grasp the general status of the National R&D programs underway and facilitate efficient implementation of R&D programs.

Source: Ministry of Science and ICT, Korea Institute of Science and Technology Evaluation and Planning, 「The report on the investigation and analysis of the National Research and Development Programs 2021」,August 2022

Source: Korea Institute of Science and Technology Evaluation and Planning, 「The Evaluation of Regional Science and Technology Innovation Capacity 2021」, January 2022

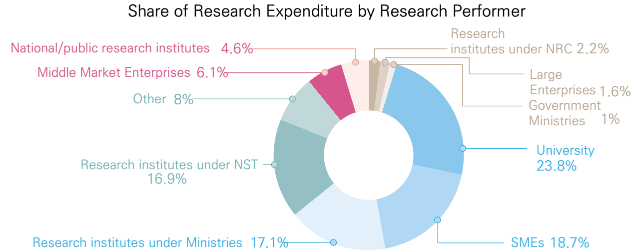
Implementation status of the total National R&D programs

Expenditure of the National R&D programs & Number of specific projects

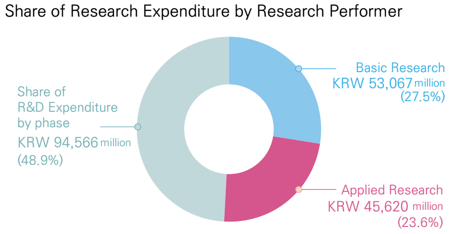


Implementation status by Major National R&D programs

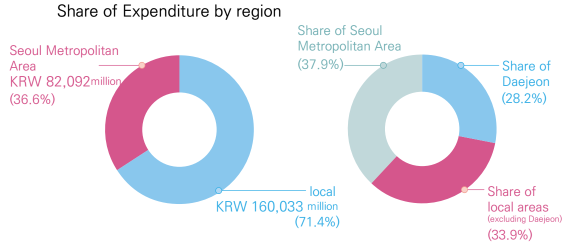
Share of Research Expenditure by Research Performer



Share of Research Expenditure by Research Performer

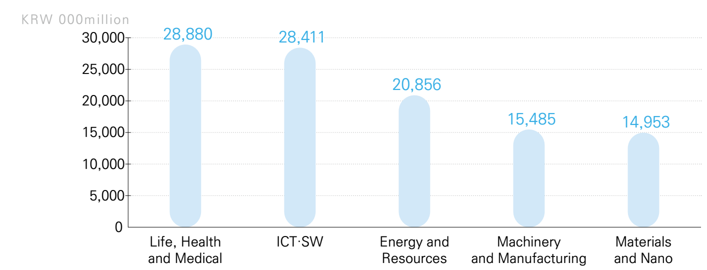


Share of Expenditure by region

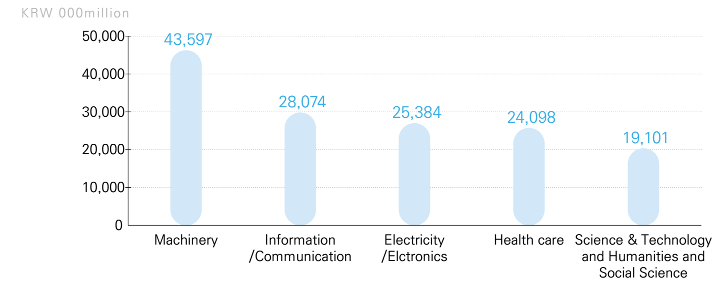


Implementation status of Major Technology Sectors

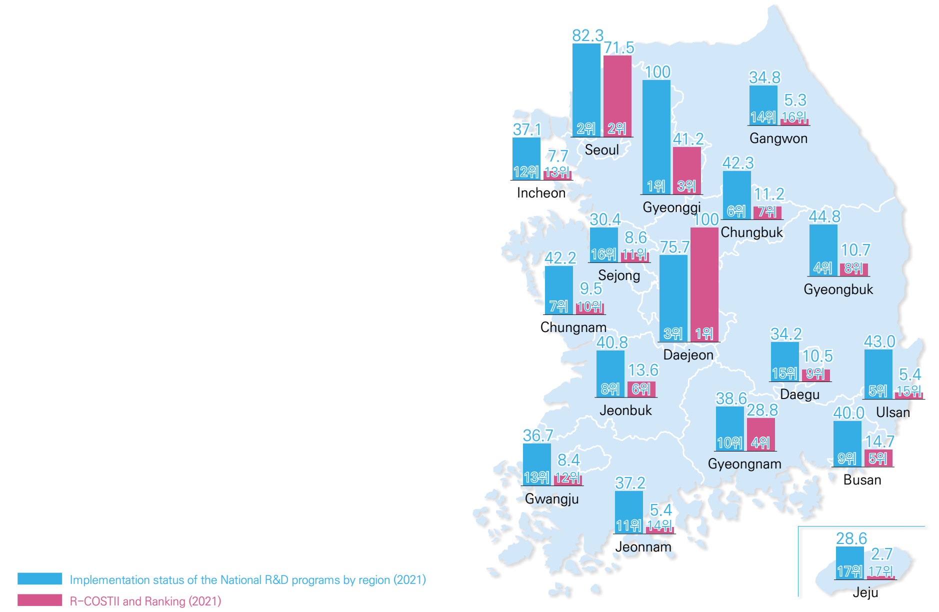
Implementation status of Core Science and Technology sectors



Implementation Status of Top 5 areas by National Science and Technology Standard Classificatic



Regional COSTII and Implementation status of the National R&D programs



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