White Paper on Science and Technology (2023–2026)

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Chapter 1 Introduction: Vision 2035 for Science and Technology Development

Technological innovation and rapid societal changes have accelerated globalization, elevated the value of industries, and introduced smarter ways of living. The integration of emerging technologies has expanded everyday applications, created a smart living environment, and changed the way people live. For instance, the advancement of information and communication technology has dissolved spatial and temporal constraints, thus bringing countries closer to each other and altering the world's economic and trade patterns by facilitating faster and more efficient global communication and transactions. The vigorous development of artificial intelligence has expedited industrial research and development, giving birth to a multitude of novel business models that have changed the value chain of industries.

The 11th National Science and Technology Conference held in December 2020 was focused on the vision of Innovation, Inclusiveness, and Sustainability. Discussions at the conference were centered on four principal topics: talent cultivation and value creation, research and foresight, economy and innovation, and secure society and smart living. The aim of the conference was to promote a dialogue between technology and civilization, boost science and technology development, use technology to improve quality of life, and respond to new societal demands/challenges, thereby building a smart society that puts the needs of people at the core. The National Science and Technology Development Plan (2021–2024) was established upon the conclusions reached at the conference and the consensus of industry experts, citizens, and ministerial representatives.

Situations both at home and abroad have changed dramatically since the National Science and Technology Development Plan (2021–2024) was published two years ago. The Russian–Ukraine War has triggered a new round of competition and cooperation among the United States, Europe, China, and Russia, and also fortified the decline of globalization caused by COVID-19 and the US–China trade war, consequently leading to the rise of geographical localization, regionalization, and conservatism. To respond to the risk of geopolitical restructuring, global trends in net zero emissions and environmental sustainability, aging population and declining birth rate, and demand for skilled professionals/talents, we should leverage the power of technology to guide Taiwan every step of the way in overcoming the difficult challenges ahead as it completes the profound transformation of its economy, society, environment, and politics. In addition to continuous investments to maintain its competitive edge in certain technologies, we must preemptively prepare for revolutionary technologies that may reshape the future, and solidify the foundation that Taiwan has in science and technology to promote economic transformation. We must also appreciate the importance of appropriate technologies that can promote inclusiveness and respond to the needs of people, thereby ensuring a just transition for the society of Taiwan; actively invest in environmental technologies for sustainable development and the 2050 net-zero transition; and speed up the development of national security technologies to help consolidate democracy.

For this reason, the current issue of White Paper on Science and Technology offers a global perspective and forward-thinking mindset to lay out a comprehensive national science and technology development policy that sets “forward-looking innovation, democracy and inclusiveness, and resilience and sustainability” as the vision for advancing Taiwan toward 2035, and drives the transformation of the entire country through technology. It has four features: 1) Addressing the daily needs of people and the challenges of society and demonstrating the value of technology and its contribution to inclusiveness, and resilience; 2) Considering the development of Taiwan as a whole in the planning of science and technology R&D as the National Science and Technology Council serving as the integrator and coordinator in the government in terms of science and technology development; 3) Spearheading the seamless integration of science and technology R&D with industrial applications; and 4) In response to geopolitical changes, developing cutting-edge strategic technologies, and expanding technological cooperation with democratic countries.

Meanwhile, we will work closely with academic communities to refine our mechanism for selecting research topics and link it to issues that critically affect the social development of Taiwan and to science domains that benefit the well-being of the public. Thus, we respond to the needs for the transformation of Taiwan and seek technological solutions to social, environmental, and economic challenges that the country is currently facing. Under the guidance of policies, we will leverage industrial resources to enhance the general science and technology capacity of Taiwan, thereby achieving the following ten general goals to materialize our vision of technology development towards 2035—forward-looking innovation, democracy and inclusiveness, and resilience and sustainability:

1. Promote gender equality, inclusive technology, and Appropriate Technology.
2. Invest in basic scientific research, and promote R&D of technologies in response to the needs of the society.
3. Develop cutting-edge strategic technologies and an independent national defense industry.
4. Build an open, secure, and trustworthy data governance system.
5. Accelerate digital transformation and net-zero transition of all industries.
6. Set up, maintain, operate, and develop infrastructures for a resilient society.
7. Promote technological innovation and transformation of the software and service industries.
8. Develop advanced manufacturing hubs and next-generation manufacturing industries.
9. Create a comprehensive diplomatic strategy that is driven by democracy and technology.
10. Promote open and innovative talent development and vocational training.

After the vision is established and the ten general goals are set, the White Paper on Science and Technology (2023–2026) then probes further into 20 key issues with respect to society, scientific research, economy, environment, politics, and strategies in order to pinpoint the problems and challenges that Taiwan might encounter as it advances towards 2035 and subsequently, to propose specific strategies to address them. Additionally, five overarching strategies will be presented for consolidating the foundation of science and technology R&D in Taiwan.

The first strategy is to build a R&D system for science and technology development that is inclusive and features integration capabilities. This system must be able to effectively mobilize and distribute public and private resources, encourage citizen participation to garner public support for the investment in technology development, and establish consensus on resource inputs for advanced innovative technologies. Second, an ecosystem of innovation that embraces the spirit of openness and people-oriented value must be developed to enhance innovation capacity for science and technology development and build a technologically empowered industrial environment. Third, technological empowerment and interdisciplinary talent development must be promoted to offer greater flexibility in fostering technological capability, optimize talent development and talent recruitment processes, and strengthen international exchange and cooperation. The fourth strategy is initiating multifaceted cooperation with international entities to maintain advantages and autonomy in scientific research, and gaining access to international markets and resources through bidirectional research exchange with reliable countries to strengthen Taiwan. Finally, a regulatory framework that is flexible and adaptable to innovative technologies must be established, while public servants' competence must be enhanced. In doing so, the development and application of science and technology will be free from the limitations of existing regulatory frameworks, thereby unlocking infinite possibilities.

These five overarching strategies, in combination with strategies in the five aspects, will guide our application of technological achievements to overcome the challenges and difficulties that Taiwan might face. Moreover, technology will turn into the driving force of Taiwan's transformation and ultimately realize an ideal life in which national security is ensured, a safe society is fostered, and citizens can live with peace of mind. In striving toward Vision 2035, we need to build an open society to support innovation, maintain stable democratic institutions to achieve inclusion, promote interdisciplinary integration to realize environmental sustainability, devise this strategic plan of science and technology development in a forward-looking perspective, and leverage the power of technology to drive comprehensive transformation of the country.

As elaborated in the above discussion, the current issue of the White Paper on Science and Technology envisions transforming Taiwan into a democratically inclusive country that engages in forward-looking innovation and is resilient and sustainable by 2035. Accordingly, different key issues are identified and analyzed, and strategies are proposed to address these issues. The paper is structured as follows: Chapter 1, titled Introduction: Vision 2035 for Science and Technology Development, introduces the vision for science and technology development towards 2035: forward-looking innovation, democracy and inclusiveness, and resilience and sustainability, which align with the universal values of environmental sustainability and social responsibility, and addresses the challenges that we face, including geopolitical risks, net zero emissions, and an aging society, as we are committed to achieving the Sustainable Development Goals of the United Nations and the 2050 net zero transition. This chapter is also focused on collaboration across ministries and various sectors to deploy key technologies (aerospace, national defense, precision health) and achieve gender and generational balance in talent cultivation, thereby realizing the value that technologies bring to humanity and society. Chapter 2, titled Science and Technology Development in Taiwan, introduces the policy-making mechanism of Taiwan's science and technology policies, analyzes global trends in science and technology development strategies, illustrates resource distribution and effectiveness evaluation of science and technology development in Taiwan, and details the implementation and results of major science and technology policies. Chapter 3, General Goals, describes each of the ten goals and their approaches. Chapter 4, Science and Technology Development Strategies and Measures, specifies issues that are critical to Taiwan's science and technology development, strategies, and the five overarching strategies with respect to the scientific research system, innovation capacity and ecosystem of innovation, talent cultivation, international cooperation, and regulatory framework. Chapter 5 concludes the White Paper, highlighting how the goals proposed in this White Paper can help Taiwan craft a response in aspects of society, scientific research, economy, environment, politics and strategy, as well as actions across ministries and government agencies to overcome challenges with the power of technology, thereby achieving Vision 2035 for science and technology development —

forward-looking innovation, democracy and inclusiveness, and resilience and sustainability.

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Chapter 1

Introduction

Chapter 2

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Chapter 2 Science and Technology Development in Taiwan

This chapter introduces the current status of science and technology (S&T) development in Taiwan. Contents include the formation mechanism of S&T policies of Taiwan, analysis of global trends in S&T policies, explanation of resources available to and effectiveness of S&T development, and the implementation and achievements of major S&T policies. Section 2.1 delves into the formation mechanism of S&T policies of Taiwan and analysis of global trends in S&T policies, describing in detail the S&T organizations of the Taiwan government, major conferences/meetings held recently by the government in relation to S&T, and analysis of major national S&T policies. Section 2.2 delineates the resources available to and effectiveness of S&T development, presenting an overview of budgets and funds that the Taiwan government has invested in S&T and status of human resources. It also analyzes the global competitiveness indicator rankings of Taiwan. Section 2.3 focuses on the implementation and achievement of major S&T policies, describing major policies and plans of the Taiwan government, academic research results, overview of science park development, and current status of international cooperation.

2.1 Formation Mechanism of S&T Policies of Taiwan and Analysis of Global Trends in S&T Policies

2.1.1 S&T Organizations of the Taiwan Government

The Executive Yuan established the National Council on Long-Term Science Development in 1959 to promote matters related to the S&T development of Taiwan. The council has undergone years of organizational restructuring and reform, the S&T development system and formation mechanism of S&T policies in Taiwan have gradually become more complete. To further establish guidelines and principles for S&T development in Taiwan, the government promulgated the Fundamental Science and Technology Act in 1999, providing an important basis for such activities.

S&T organizations in Taiwan can be divided into three levels: Organizations that implement execute S&T policies, and entities in charge of S&T planning and evaluation. Organizations that implement S&T policies include the National Science and Technology Council (NSTC) and other agencies (units) associated with it, and the Office of the Board of Science and Technology (BOST), which is in charge of assisting with the review of national S&T development policies and organization of the Strategic Review Board (SRB) meetings. BOST merged with the NSTC in July of 2022 and was renamed the Office of Science and Technology Policy (OSTP). The NSTC is tasked with planning S&T development vision, allocating S&T budgets, supporting fundamental research, improving science parks, promoting innovative entrepreneurship, reviewing/managing S&T plans/projects, formulating national S&T visions and forward-looking blueprints, setting policy goals for the government, and overseeing the segregation and coordination of duties across ministerial departments. Each agency (unit) enforces governmental policies on S&T development with the allotted budgets, while Executive Yuan officials are responsible for coordinating policy implementation across ministries.

In 2022, the Executive Yuan reorganized the Ministry of Science and Technology (MOST) into the NSTC and established the Ministry of Digital Affairs (MODA) to facilitate the digital transformation of Taiwan. The MODA is tasked with promoting the digital development of industries in the areas of communications, information, cyber security, internet, and media, overseeing digital governance and infrastructure, boosting the development of digital economy, and accelerating the nation's digital transformation. The Department of Cyber Security was reorganized as a subordinate agency of MODA into the Administration for Cyber Security. The Administration is responsible for implementing national cyber security policies to effectively improve the cyber security of Taiwan, as well as matters relating to cyber security defense mechanisms for national critical infrastructures, cyber security-related drills at the national level, and cyber security education and training. The Administration for Digital Industries was also established as the competent authority in charge of digital economy development in Taiwan. The Administration oversees policy planning and drafting of laws for digital economy industries, the promotion of applications relating to digital technology, and industry talent training. It also helps industries in Taiwan to prepare for challenges and opportunities in the era of digital economy.

S&T policies of Taiwan are implemented at the ministerial level and also by various organizations, including Academia Sinica, national universities and colleges, research organizations, and public/private organizations. Academia Sinica, ministries, and national universities and colleges are mainly involved in fundamental research and applied research. Research organizations specialize in applied research, whereas other public/private organizations are focused on research commercialization.

Entities in charge of S&T planning and evaluation are involved in project planning and review, project implementation management, and results evaluation. Project planning and review includes the formulation of annual plans and medium-/long-term projects. Project implementation management is to ensure that projects are implemented as scheduled. Finally, project results are evaluated and examined to provide a reference for revisions or improvements.

The government organizes conferences and meetings, including the National Science and Technology Conference, Executive Yuan Strategic Review Board (SRB) meetings, Science and Technology Advisory Group meetings, Science and Technology Development Consultation meetings, and New Economic Development Consultation meetings, to establish consensus and determine the direction of national S&T policies.

2.1.2 Science and technology-related conferences and meetings held in Taiwan

(1) National Science and Technology Conference

The Executive Yuan convenes the National Science and Technology Conference once every four years in accordance with the 1999 Fundamental Science and Technology Act, treating it as a central platform for discussing and formulating S&T policies. After the conference, a National Science and Technology Development Plan is drafted and approved, forming the basis for governmental departments to promote S&T development.

The 11th National Science and Technology Conference was held in 2020. The vision of making Taiwan innovative, inclusive, and sustainable by 2030 was proposed at the conference, and discussions were centered on four main aspects: talent cultivation and value creation, research and foresight, economy and innovation, and secure society and smart living. After the conference, then the MOST (now NSTC) consulted with relevant ministries and administrations and established the National Science and Technology Development Plan (2021–2024) upon the conclusions drawn at the conference. The plan consisted of 4 goals, 15 subgoals, 44 strategies, and 134 measures related to each strategy and was implemented by relevant agencies (units).

(2) Executive Yuan Strategic Review Board (SRB) meetings

The Executive Yuan has hosted 13 strategic meetings on electronics, information and telecommunications since 1992 and another 5 meetings on biotechnology since 1997 to facilitate the development of these industries. In 2002, these meetings were consolidated into a single meeting, called Strategy Review Board (SRB) meeting, to expand the scope of meeting topics, ensure that issues discussed are aligned with current industrial development, and collect constructive advices on science and technology from various industries. Depending on the general needs of industries in Taiwan for S&T development, a specific industry is selected each year to be the focus of SRB meetings.

The SRB meetings hosted by the government in recent years are described below:

A. SRB meeting on 5th generation (5G) mobile network applications and industrial innovation

The revolution of 5th generation (5G) mobile networks in the future will drive the transformation and upgrade of industries in Taiwan. In addition, combining 5G networks with artificial intelligence (AI), Internet of Things (IoT), augmented reality, virtual reality, 4K/8K audio-visual and edge computing technologies will greatly benefit the vertical application of smart medicine, smart factory, smart city, and unmanned aerial vehicles, which in turn promotes the digital transformation of Taiwan. In October 2018, the Executive Yuan held the SRB meeting on 5th generation (5G) mobile network applications and industrial innovation. Topics discussed at the meeting included the application of and development strategies for 5G technologies, the spectrum of and regulations on 5G technologies, the innovation and entrepreneurship in a 5G era, a future of mobile smart living, and the smart application and development of 5G technologies and promotion of 5G industries. The outcomes of the meeting provided a reference for Taiwan to implement strategies and develop visions. The main resolutions adopted at the meeting are as follows:

(A) Accelerate 5G deployment, guarantee 5G broadband accessibility in rural areas, and encourage innovation, energy conservation, and reduced carbon footprint.

(B) Build an ecosystem of 5G technologies, urge telecommunication operators to collaborate with startups, support entrepreneurial teams to develop innovative applications, and foster startups to develop novel applications for 5G technology.

(C) Focus on the development and innovative application of new 5G devices, encourage startups to develop innovative 5G applications by tapping into Taiwan's industry supply chain, and introduce innovative applications to health care, logistics and transportation, public utilities, and smart city infrastructure.

(D) Relax regulations, continue to examine laws and regulations on innovation and development, streamline policy tool application procedures, utilize the space created by the regulatory sandbox, and make use of data on the premise that personal information and privacy is protected.

(E) Direct domestic venture capitals and investments to startups, construct an environment that supports new 5G businesses, demonstrate new applications, and ramp up efforts to attract 5G talents from science and technology, economy, and education sectors.

(F) Develop telecommunication and cyber security technology, build self-defense capability, set up stable, reliable platforms and systems that detect 5G technology and maintain cyber security, and verify cyber security attack–defense mechanism to improve cyber security capability.

B. SRB meeting on smart living display technologies and applications

To create the 2030 vision of a smart-tech lifestyle by taking advantage of Taiwan's display technology and application industries and integrating 5G into smart technologies such as Artificial Intelligence of Things (AIoT), the Executive Yuan hosted a SRB meeting on smart living display technologies and applications in July 2019. The meeting was focused on three issues: new business opportunities driven by smart living needs; a blueprint of developing display technologies for smart living; and interdisciplinary collaboration and environment for industrial development. The objective of the meeting was to identify business opportunities derived from the application of display technologies in the future of smart living, thus keeping Taiwan's advanced tech industry at the global forefront. The meeting concluded that:

(A) Combining display industry with smart technologies and applications enables the integration and development of diverse systems, and plans should be devised to ensure a stable supply of resources for technological reinforcement.

(B) Collaboration between industrial, public, academic, and research sectors strengthens soft–hard integration and field testing, which contributes high-value system solutions. In addition, next-generation display system technologies should be developed to accelerate industrial transformation and value creation.

(C) The government should develop key technologies for AIoT-based smart display application systems, build a complete industrial ecosystem, relax laws to eliminate investment barriers, and foster interdisciplinary talents.

C. SRB meeting on sports and technologies in Taiwan

Taiwan is home to well-developed industry chains for sporting goods and equipment, in addition to a wealth of scientific research results and leading ICT industries. The Executive Yuan therefore hosted a SRB meeting on sports and technologies in November 2021. The meeting was intended to promote opportunities arising from the unification of sports, science and technology, and industries, thus making it known to citizens and students across Taiwan so as to improve the health and quality of life of Taiwanese nationals. Issues concerning industries that merge sports with technology were discussed, including creation of new values from industry upgrade, innovative business models, development of new smart applications through integration of research results and innovative technologies, and environments conducive to cross-industry smart sports and recreation. Strategies for developing industries that merge sports with technology were extensively investigated. Meeting highlights are as follows:

(A) Creation of new values from industry upgrade

Policy implementation and inter-ministerial cooperation enable faster integration of the technological capabilities of organizations and industries and facilitate the sound development of ecosystem that merges sports with technology. The following actions are recommended: a) Leverage the advantages of Taiwan's tech and sports industries to promote soft–hard integration and develop new business models, which lead to internationally competitive solutions; b) Use the deductive nature of design to develop operations and service processes for the future of sports and technology, create value, and increase the global visibility of Taiwanese brands; c) Build a sports and technology research center that focuses on sports science in order to bring innovative applications to life; d) Conduct field testing to develop the required sports science data, specifications and interfaces, and business models for virtual/physical integration and innovation, thereby building a pool of interdisciplinary talents proficient in sports and technology to promote smart sports activities in four areas of application (i.e., viewing, working out, playing, and training with technology); and e) consolidate inter-ministerial and interdisciplinary resources to create flagship demonstration applications, build international sporting events or exhibitions into sites that demonstrate innovative applications, thus giving industries opportunities for international exposure.

(B) Innovative business models

Internationalization of startups should be promoted to better operate a new incubation environment. The following actions are recommended: a) Connect international sports innovation accelerators to venture capital resources through mentorship programs, and cooperate with accelerators and venture capital firms to invest in new startups and promote technological entrepreneurship from organizations to test business models in international settings; b) Accelerate the adoption of technologies at various sites, such as incorporating scientific research results to indoor facilities and outdoor activities, so as to create sites for testing new business models, and combine sporting events with emerging technologies to develop a new way of viewing sports games, which will give rise to a new fan management model; and c) Forge links between traditional sports manufacturing industries, ICT firms, and health care industries to catalyze the creation of value for different industries, and build a new cross-industry business model that connects various sports and technology results, thereby creating new data serves with respect to financial insurance, corporate health, and geriatric health promotion.

(C) Development of new smart applications through integration of research results and innovative technologies

The government should gather interdisciplinary professionals and adopt 5G technologies, AI, and other advanced technologies to conduct sports science research. These technologies should be optimized for further application in sports that are popular in Taiwan. In terms of industrial technology, technological research results, valued-added designs, and site application/verification results should be provided for industries to build a sports technology product commercialization and transformation model that promotes the development of an ecosystem of interdisciplinary sports industries. Finally, the government is advised to create an environment that is conducive to sports scientific research and industrial development, which will catalyze the development of sports industries. This requires collaborative efforts from the Ministry of Education, Ministry of Economic Affairs, MOST (now NSTC), and Ministry of Health and Welfare, in order to promote industry–academia cooperation that will benefit the health and general well-being of Taiwanese nationals.

(D) Environments conducive to cross-industry smart sports and recreation

Industrial resources should be injected as needed to develop service demonstration applications that will become the highlight of a city and transform the city into a healthy city where sports are everywhere. An inventory of industry needs should be taken and integrated it into an interdisciplinary talent–industry matchmaking platform and also into an operational model for promoting industry–academia co-creation and integration of interdisciplinary talents who are skilled in sports technology applications.

(3)Bio Taiwan Committee (BTC) meetings

The Executive Yuan has set up the Bio Taiwan Committee (BTC) following resolutions adopted at the SRB meeting in 2004. BTC was established to plan national policies, investment strategies, development directions, and visions for the biotechnology industry, and provide a basis for policy implementations at the ministerial level. The committee has convened 16 meetings in 2005–2022.

Meetings held in 2022 were focused on visions and plans for bio resilience, use of BioData to transform the future of health, and diverse insights into new opportunities of precision health. To explore how innovative breakthroughs will bring about opportunities for biotechnology development, thereby realizing the vision of making Taiwan resilient with precision health, BTC members provided the following recommendations regarding the value chain of smart and precision medicine:

A. Resilience in biomedicine

(A) Build a chain of resilient industries in Taiwan: Enhance national resilience in public health and pandemic prevention by developing capabilities to independently manufacture and supply strategic drugs and vaccines, etc.; review and revise national health insurance systems for coverage of patented medications that have expired; clarify the position and strategy of Contract Development and Manufacturing Organization (CDMO) and establish a comprehensive ecosystem of emerging medicine and supporting measures.

(B) Boost the development of biotechnology industry through investments by the government: Combine ICT industry, set up large medical device investment companies, and develop internationalized healthcare services to promote the rapid advancement of telemedicine technology; set up large venture capital or private equity funds for health disparities, promote the development of unicorn companies, consider industries for national development angel investment funds, and raise investment limit; relax investment restrictions on medical organizations in hopes of spurring the collective development of hospitals and Bio-ICT industries.

(C) Foster international interdisciplinary talents, fortify international ties, and build new science park models: Establish a mechanism for early investment in academic and research sectors to facilitate the entrepreneurship of basic science talents, and cultivate professional talents and interdisciplinary cooperation; strengthen international ties and talent leadership; take an inventory of medical technologies over which Taiwan has an advantage, assist with adoption of such technologies in domestic hospitals, build a specialty demonstration site, and introduce training programs for overseas physicians and health professionals, in order to facilitate the turn-key transfer of featured medical technologies in the future.

(D) Develop market entry mechanism for innovative pharmaceutical products: Create an out-of-pocket payment system, increase health insurance funds, or introduce commercial medical insurance to cover innovative pharmaceutical products so that patients have the opportunity to choose the best biomedical product; establish insurance coverage standards for innovative (smart) medical devices;

and perform a trial run of the "Health Insurance Sandbox" while analyzing its cost effectiveness during the trial run period.

B. BioData

(A) Improve data governance supervision mechanism: Government departments should draw up specific laws or amend relevant laws within three years and include an independent supervision mechanism for personal information; data governance for data reuse should include data subjects as stakeholders and adopt information technology to assist data subjects to participate in data governance, thereby building public trust in use of data; the development of data use business models, common interests, and the management of data derived from human biological data must be regulated as soon as deemed necessary for the nature of that data.

(B) Integrate medical data specifications into a mechanism for use of medical data: Establish international standards for the storage, application, and verification of biomedical data in Taiwan to facilitate data collection, application, and authentication; strengthen data application by connecting databases in series; provide incentives for academic and research communities to increase the value of databases; and develop cloud data storage solutions.

(C) Establish for-profit global health big data companies that act in the interests of the public: Develop global companies by using sustainable business model to create maximum value; recruit international talents for government programs, form a shadow team, and develop appropriate laws and regulations; establish feedback mechanism to promote the development of biotechnology and pharmaceutical industries.

C. Bio-ICT

(A) Promote Bio-ICT applications in medical health care markets: Build BioDesign Taiwan, an innovative medical device incubation system; make use of wearable medical equipment and devices to accelerate clinical trials, and take clinical trials outside of hospital settings; establish applicable laws as early as possible to avoid ethical disputes caused by smart medical products; use integrated verified data and Software as Medical Device (SaMD) to prioritize promoting the use of Bio-ICT applications in hospitals across Taiwan, and have hospitals establish companies to facilitate the establishment of models for commercial use.

(B) Accelerate the transformation of hospital information systems: Set up next-generation healthcare/hospital information systems (HIS) in line with international standards; formulate policies that provide rewards and incentives to encourage the digital transformation of healthcare institutions to promote smart health care; the government should designate public private partnership (PPP) or public welfare platforms to help healthcare institutions standardize the digital architecture of their cloud-based electronic medical record systems and information exchange.

(C) Launch telemedicine services: Draft plans for accessibility to virtual clinics so that doctors may practice in non-physical medical institutions; establish standards that protect the cyber security of telemedicine platforms, which in turn enable private organizations to develop telemedicine systems that can ensure the protection of personal information.

2.1.3 Analysis of key national S&T policies

According to the 2021 Science, Technology and Innovation Outlook published by the Organization for Economic Co-Operation and Development (OECD), science and technology offer the best export from COVID-19. Scientific research and technology development have played essential roles in pandemic control and vaccination policies since the outbreak of COVID-19. The pandemic has also stretched research and innovation systems to their limits, revealing policy gaps that need filling. To improve existing systems and avoid future global crises, S&T and innovation policies must be recalibrated to assist the government more effectively and strengthen research and innovation capabilities to achieve social sustainability, inclusivity, and resilience goals. Against this backdrop, the vision of key national S&T policies and policy contents are summarized below:

(1) Vision of key national S&T policies

Countries worldwide typically propose technology visions, goals, key S&T focuses, and other prospective needs and plans by taking into consideration their R&D capability, industry characteristics, economic structure and outlook, natural resources, strategic approaches of major competitors, their inherent strengths and weaknesses, among other intrinsic and extrinsic conditions, and current condition of the nation.

In recent years, the world has been subject to impacts resulting from supply chain disruptions and labor shortages due to COVID-19, rise of economic nationalism due to US–China trade war, food and energy crises caused by Russia–Ukraine war, and frequent natural disasters caused by climate change. In response, countries around the world have proposed technology visions and key implementation plans, which can be roughly categorized as follows: Basic scientific research and innovation, inclusive society and people-oriented value, carbon sustainability and increased national resilience.

A. Basic scientific research and innovation

Technology-oriented countries such as European Union (EU) nations, Japan, South Korea, Singapore, and China have presented national scientific research plans in recent years, the key points of which are briefly described below: EU nations will expand the scope of its investments in the research and innovation of health, digital industries, climate, and bioeconomy issues and envision becoming a leader in the innovation market. Singapore is committed to developing a digital economy and a smart nation to cement its global position in terms of technology, innovation, and business. South Korea looks toward 2040, with a focus on future technology and digital transformation, among other issues, to address solves future societal problems and achieve a leading competitive position in global technology. Japan proposes to focus on beyond fifth-generation (B5G) networks and developing revolutionary technologies by 2050, unleash Japan's basic research capabilities, and use knowledge to solve social problems, thereby realizing the general vision for the well-being of humans. China released its Outline of the 14th Five-Year Plan for National Economic and Social Development and Vision 2035 of the People's Republic of China, which will step up research and innovation efforts in the areas of integrated circuits, aerospace, ship and ocean engineering equipment, robots, advanced rail transport equipment, and pharmaceutical healthcare equipment.

B. Inclusive society and people-oriented value

Finland places value on inclusive and sustainable development and aims to achieve fair, equal and inclusive national governance through the establishment of rule of law and equality in employment market. The first female Prime Minister of Sweden, who took office in 2021, proposed to focus on a crackdown on racial segregation and criminal activities and increase government control over social welfare systems, so that Sweden, which is home to innovation, competitive enterprises, and high-quality labor, can unleash its potential to become a better country.

C. Carbon reduction sustainability and increased national resilience

Many countries attach importance to policies related to carbon reduction sustainability and national resilience. With respect to national resilience, the United States strengthens its resilience by reinforcing its manufacturing sector, supply chains, and national security to cement the leading position of its local semiconductor manufacturers and future industries. EU nations are also supporting its semiconductor ecosystem and strengthening resilience to ensure a secure supply chain, reduce their dependence on external entities, and prepare for key technology, security, and social challenges. With regard to carbon reduction sustainability, countries such as Finland, Sweden, and China have presented policies to reduce carbon footprint and achieve sustainability. The UK proposed a plan for green industrial revolution, which involves increasing R&D investments in new technologies for energy, transportation, carbon reduction, construction, environment, and finance. Denmark presented a comprehensive green agreement, emphasizing reforms in healthcare, carbon reduction technology, and green taxation to accelerate its green transition. China also described green development directions in its 14th Five-Year Plan, to power effective measures for carbon neutrality by 2060.

(2) Key national S&T policies

The world's technologically advanced countries such as US, EU, and UK, small innovative countries such as Sweden, Denmark, Finland, and Singapore, and Asian countries such as China, Japan, and South Korea, have proposed key S&T development strategies, in order to tackle complex situations around the world resulting from post-pandemic impacts, climate change, the US–China technology war, and geopolitical issues. These strategies also include plans for frontier technologies, visions for future development based on their strengths and weaknesses, main strategies, and key development projects, which are described in detail below:

A. United States

During Obama's term as president of the US, policies supporting reindustrialization and Bringing Manufacturing Back Home were already in place; however, these policies have been ineffective but they are gradually taking a more definite form in the minds of people. During Trump's term as president, numerous science research and development plans were proposed, including the 2020 National Strategy for Critical and Emerging Technologies, which aimed to strengthen the country's innovation infrastructure to prevent enemy states from illegally obtaining key emerging science and technological achievements of the United States, and to actively develop advanced technologies such as quantum computing, conventional weapons, materials, aviation engines, artificial intelligence, autonomous driving, nuclear, biological, chemical (NBC) weapons, communication networks, data science and storage, blockchain, energy, health care and public health, semiconductors, and other key technologies.

In June 2021, the U.S. Senate adopted the United States Innovation and Competition Act, bringing together multiple bills, including the

Endless Frontier Act and Strategic Competition Act, into one legislative package that invests in key emerging technologies, science talent development, organizational reform, industrial promotion, trade, and national security, etc.

On August 9, 2022, President Biden signed into law the CHIPS and Science Act (CHIPS: Creating Helpful Incentives to Produce Semiconductors), which will strengthen American manufacturing, supply chains, and national security, and invest in nanotechnology, clean energy, quantum computing, and artificial intelligence to keep the United States the leader in the industries of tomorrow. The CHIPS and Science Act provides US$52.7 billion for American semiconductor research, development, manufacturing, and workforce development. This includes:

(A) US$39 billion in manufacturing incentives, including $2 billion for the legacy chips used in automobiles and defense systems.

(B) US$13.2 billion in R&D and workforce development.

(C) US$500 million to provide for international information communications technology security and semiconductor supply chain activities.

(D) A 25% investment tax credit for capital expenses for manufacturing of semiconductors and related equipment.

(E) The Act will establish a technology, innovation, and partnerships directorate at the National Science Foundation (NSF) to focus on fields such as semiconductors and advanced computing, advanced communications technology, advanced energy technologies, quantum information technologies, and biotechnology. It will strengthen commercialization of research and technology, ensuring that what is invented in America is made in America.

(F) The Act will also reauthorize and expand fundamental and use-inspired research at the Department of Energy Office of Science and the National Institute of Standards and Technology to sustain U.S. leadership in the sciences and engineering as the engine for American innovation.

These incentives will secure domestic supply, create good-paying jobs and high-skilled manufacturing jobs, and catalyze hundreds of billions more in private investment. In addition to strengthening the US local semiconductor supply chain, the U.S. government also united the strengths of its allies, announcing in March 2022 the idea of forming the “Chip 4” alliance with Taiwan, Japan, and South Korea.

B. EU nations

Climate change is the current century’s biggest challenge, presenting opportunities to establish new economic models. In December 2019, the European Commission presented the European Green Deal, setting the blueprint for its transformational change.

All 27 EU Member States committed to turning the EU into the first climate neutral continent by 2050. To get there, they pledged to reduce carbon emissions by at least 55% by 2030, compared to 1990 levels. In June 2021, the European Climate Law entered into force, incorporating the two 2030 and 2050 goals to strengthen its binding legislation.

To achieve the aforementioned carbon reduction targets, the European Green Deal also includes the following goals: a) Making transport sustainable for all through 50% and 55% reduction of emissions from vans and cars, respectively; b) Leading the third industrial revolution by renovating 35 million buildings and creating 160,000 additional green jobs in the construction sector; c) Cleaning our energy system by achieving 40% new renewable energy target and 39% energy efficiency targets for final and primary energy consumption; d) Renovating buildings for greener lifestyles by requiring Member States to renovate at least 3% of the total floor area of all public buildings annually and setting a benchmark of 49% of renewables in buildings; e) Working with nature to protect our planet and health by achieving a new target of 310 Mt for natural carbon removals; and f) Boosting global climate action with the following targets: 30% of the EU’s Neighborhood, Development and International Cooperation Instrument (NDICI) supports climate objectives and 1/3 of the world’s public climate finance comes from the EU and its Member States.

In September 2021, the European Commission adopted the New European Bauhaus, which includes a number of policy actions and funding possibilities. The project aims at accelerating the transformation of various economic sectors in order to provide access to all citizens to goods that are circular and less carbon intensive. The New European Bauhaus brings a cultural and creative dimension to the European Green Deal, aiming to demonstrate how sustainable innovation offers tangible, positive experiences in our daily life. For the funding, there will be about €85 million dedicated to New European Bauhaus projects in 2021–2022. Many other EU programs will integrate the New European Bauhaus as an element of context or priority. Funding will come from different EU programs including the Horizon Europe program for research and innovation (notably the Horizon Europe missions), the LIFE program for the environment and climate action and the European Regional Development Fund.

Since 1983, the European Union has been proposing 5–7-year research projects under the Framework Programme (FP) to support EU-level research and innovation policies. The latest FP9 Horizon Europe (2021–2027) is an EU scientific research initiative that was drafted and approved by the European Commission in June 2018 and was launched on January 1, 2021. The budget for Horizon Europe was raised to nearly €100 billion from the €80 billion for the Horizon 2020. The 7-year Horizon Europe aims to invest in research and innovation projects to shape the future of Europe for European citizens. Its overarching goals are to strengthen the EU's scientific and technological bases, to boost Europe's innovation capacity, competitiveness and jobs, and to deliver on citizens' priorities and sustain socio-economic model and values.

Horizon Europe is the world's largest multi-year research and innovation program aimed at making Europe a front runner in market-creating innovation. This program is primarily focused on research and innovation investments, such as strengthening investments and research on high-tech professionals or enhancing EU's industrial competitiveness and innovation capacity through the European Innovation Council and

European Institute of Innovation and Technology. Horizon Europe creates value in that it generates more Gross Domestic Product (GDP) profit for every euro invested in research and innovation, contributes more than 35% of its budget to climate action, and creates up to 300,000 new highly qualified jobs by 2040. It is composed of three pillars:

(A) Excellent Science

This pillar reinforces the excellence of EU's science base through the European Research Council, Marie Skłodowska-Curie Actions, and Research Infrastructures.

(B) Global Challenges & European Industrial Competitiveness

This pillar is organized into six clusters: Health; Culture, Creativity & Inclusive Societies; Civil Security for Society; Digital, Industry & Space; Climate, Energy & Mobility; and Food, Bioeconomy, Natural Resources, Agriculture & Environment.

(C) Innovative Europe

This pillar aims to stimulate education, research and ecosystems conducive to innovation through European Innovation Council and European Institute of Innovation and Technology.

In order to strengthen international cooperation and maximize innovation capacity across EU, Horizon Europe supports transnational scientific researchers and experts to tackle global societal challenges together. It also integrates the research and innovation potentials of EU Member States, providing other funding to support research and innovation. Reinforcing science openness, including open access to publication and research data, is the key principle of Horizon Europe for stimulating and enhancing research and innovation results.

Given the fundamental roles of integrated circuit (IC) in the digital economy and the concentration of geopolitical relations and production in specific areas, the EU should support the development of semiconductor ecosystems, ensure the resilience of supply chains, and reduce external dependencies. In December 2020, 22 Member States jointly signed the Declaration: A European Initiative on Processors and semiconductor technologies, agreeing to work together to reinforce the processor and semiconductor ecosystem and to expand industrial presence across the supply chain, in order to address key technological, security and societal challenges. The European Commission proposed a Digital Compass in March 2021, one of the goals of which is having 20% of the world's cutting-edge and sustainable semiconductors to be produced in Europe by 2030. This goal is reiterated in the Path to the Digital Decade in the 2030 Policy Programme.

To realize the vision for the development of the semiconductor industry, the European Chips Strategy is articulated around five strategic objectives:

(A) Strengthen research and technological leadership to preserve its assets in breakthrough technologies.

(B) Build and reinforce innovation capacities in the design, manufacturing, packaging of advanced, energy-efficient and secure chips, and the capability, integrating different technologies to produce complete product lines.

(C) Put in place an adequate framework to increase European chips production by 2030, create favorable conditions for private investments, and reinforce the security of supply of chips.

(D) Address skills shortages, attracting talent and supporting the emergence of a skilled workforce.

(E) Develop an in-depth understanding of global semiconductor supply chains to monitor operations, understand future trends, and anticipate possible disruptions, and build balanced and reciprocal international partnerships with likeminded partners.

C. United Kingdom

The UK is the first country in the world to commit to ending climate change by law. In November 2020, UK announced the ten point plan for a green industrial revolution, systematically planning net-zero carbon strategies for various economic sectors while using greenhouse gas removal technologies to achieve its net zero emissions target by 2050. The UK government also drew up an energy transition plan for the next 30 years, which is expected to unlock £90 billion of private investment and create 440,000 new green jobs, and approached climate problems with four key principles: 1) Work with the grain of consumer choice: no one will be required to rip out their existing boiler or scrap their current car; 2) Ensure the biggest polluters pay the most for the transition through fair carbon pricing; 3) Ensure that the most vulnerable are protected through Government support in the form of energy bill discounts, energy efficiency upgrades, and more; 4) Work with businesses to continue delivering deep cost reductions in low carbon tech through support for the latest state of the art kit to bring down costs for consumers and deliver benefits for businesses.

The focus of the ten point plan includes the following:

(A) Offshore wind and modern ports: Produce 40GW of offshore wind and invest £160 million into modern ports and manufacturing infrastructure by 2030.

(B) Hydrogen: Develop 5GW of low carbon hydrogen production capacity and provide £240 million Net Zero Hydrogen Fund by 2030.

(C) Advanced nuclear power: Commit £240 million investment into Small Modular Reactors and £170 million for a research and development programme on Advanced Modular Reactors.

(D) Zero emission vehicles: Ban the sale of new petrol and diesel cars and vans from 2030 and ban the sale of hybrid cars from 2035.

(E) Green public transport: Expand investments in zero emission buses and design cycling and walking lanes.

(F) Jet zero and green ships: Launch zero-emission aircrafts by 2030 and invest in clean maritime technology such as hydrogen-powered ships.

(G) Greener buildings: Implement the Future Home Standard in the shortest possible timeline, consult shortly on increased standards for non-domestic buildings, and aim for 600,000 heat pump installations per year by 2028.

(H) Carbon capture, usage and storage (CCUS): Establish CCUS in two industrial clusters by mid 2020s, and aim for four of these sites by

2030, capturing up to 10 Mt of carbon dioxide per year.

(I) Protecting our natural environment: Invest £5.2 billion in flood and coastal defenses and 10 long-term Landscape Recovery projects over the next four years.

(J) Green finance and innovation: Commit to raising total R&D investment to 2.4% of GDP by 2027, and in July 2020 published the UK Research and Development Roadmap, which aims to bring down the cost of the net zero transition, nurture the development of better products and new business models, and influence consumer behavior.

D. Sweden

A new policy based on the slogan "Sweden Can do Better" was proposed in 2021 to focus on cracking down on violence and criminality caused by racial segregation, driving green transformation and green revolution, and exerting increased government control over the social welfare system. Sweden today has an innovative and competitive business sector and skilled workers. The objective of this new policy is to unleash Sweden's inherent potential so that the Sweden today can do better.

Regarding climate change, the Swedish government has formulated relevant policies in addition to declaring its determination to achieve net-zero emissions and net-zero transition. In response to EU's policies and new laws relating to net zero emissions, the Ministry of Infrastructure of Sweden published in 2022 the National Electrification Strategy– a secure, competitive and sustainable electricity supply for a historic climate transition, which comprised twelve areas categorized into five dimensions:

(A) Planning and cooperation: Enhanced planning to meet a sharp increase in need for electricity by 2045, and establish collaboration, roles and responsibilities for the public sector, industry and other community stakeholders.

(B) Efficient use of power and energy: Energy efficiency, power and resources, a well-integrated energy system, and greater flexibility in use of electricity and storage.

(C) New infrastructure for sufficient grid capacity and electric vehicle charging: Proactive work is needed for the efficient expansion of electricity networks and charging infrastructure based on a clearer picture of needs, and shorter lead times for new electricity networks.

(D) Secured supply of power and energy: Promote secure electricity supply to remove barriers to power generation, and promote the development of improved electricity market.

(E) Implementation and endorsement: Form social contract through skills provision, knowledge promotion, and innovation.

In the same year (2022), the Swedish Ministry of Commerce published the "Future Industry—Green and Digital Transitions Strategy," which aims to make Sweden the world's first fossil-free welfare country by combining digital transformation and green transition, where digital transformation involves the use of 5G, Internet of Things, automation, artificial intelligence, and blockchain technologies to develop industrial intelligence and prompt small and medium enterprises (SMEs) to upgrade and improve their adaptation capability; and green transition achieves the goal of reducing impact on climate and slowing down biodiversity losses.

E. Denmark

Following a period of turmoil brought about by the COVID-19 pandemic, energy supply has created restrictions and uncertainties, continued population growth will make fossil fuels increasingly scarce, and global climate issues will drive countries to restrict the burning of coal, oil and natural gas. As a response to the COVID-19 pandemic and energy crisis, the Danish government and parliament have adopted a number of comprehensive green deals that will accelerate the green transition. The Danish Ministry of Finance published the Recovery and Resilience Plan in 2011, which is structured around seven strategies in combination with national funding:

(A) Strengthening the resilience of the healthcare system, which aims to invest in digital solutions for the healthcare sector, help vulnerable and elderly people with safe medical consultations, ensure the monitoring of the supply and inventory of critical medical products, conduct a large-scale clinical cohort study of the various COVID-19 vaccines, and increase the resilience and sustainability of the healthcare system.

(B) Reduction of greenhouse gas and nitrogen emissions and green transition of agriculture and environment, which aims to cut greenhouse gas emissions in the agricultural sector by using new tools, initiate a green transition in the agricultural sector, and rehabilitate industrial sites and contaminated lands.

(C) Energy efficiency, green heating, and carbon capture and storage (CCS), which aims to scale up investments in energy efficiency measures for industrial sectors, households and public buildings; mitigate the impact of COVID-19 on finance; increase job opportunities; stimulate investments in and promotion of the adoption of digital technology; improve the flexibility and energy efficiency of building CCS-potential to reduce energy costs and consumption for consumers, enterprises, and the public sector; and realize net zero emissions target through CCS.

(D) Green tax reform, which aims to reduce carbon emissions by increasing emissions tax on industry and accelerate transition away from carbon emissions activities by providing companies with incentive and the opportunity and with tax deductions for frontloading green investments.

(E) Sustainable road transport, which is achieved by reducing the greenhouse gas emissions of petrol cars, introducing a premium for scrapping old diesel cars, lowering electricity tax on charging electric vehicles, encouraging use of ride sharing services, and investing in bike lanes and urban green mobility subsidy projects.

(F) Digitalization, which aims to establish a digitalization partnership consisting of top managers and experts from the Danish business community, municipalities and regions, academia, and social partners, as well as stakeholders across society such as citizens and businesses, to contribute recommendations for digital strategy. The future of digital occupation and employment is secured through digitalization to support the growth and export of businesses and services. With the Recovery and Resilience Plan at the core, digitalization promotes a digital transformation across all sectors, advancing welfare and equality, growth and employment, and green transition.

(G) Green research and development, which aims to reduce emissions of greenhouse gases and lower the potential cost of decarbonizing the society by investing in the development of new green technologies, including the use of CCS and green fuels in transport and industrial sectors, climate-friendly agriculture and circular economy to promote green transition, digital transformation, and maintain and create new employment opportunities in the green sector.

F. Finland

The Finnish government published a government action plan in 2019 called Inclusive and Competent Finland - A Socially, Economically and Ecologically Sustainable Society, disclosing eight strategic issues: Carbon neutral Finland that protects biodiversity; globally influential Finland and policy on Europe; safe and secure Finland built on the rule of law; dynamic and thriving Finland, transport network development and agriculture; Finland built on trust and labor market equality; fair equal and inclusive Finland; Finland that promotes competence, education, culture and innovation; and governance.

In the face of the growing severity of climate change problems in recent years, the Finnish Ministry of Environment released a Medium-term Climate Change Policy Plan: Towards A Carbon-neutral Society 2035, which is based on the tightened emissions reduction obligation proposed by the European Commission for 2030. The Climate Change Policy Plan applies to the effort-sharing sector, which comprises the emissions from transport, agriculture, building-specific heating, non-road mobile machinery, waste management and greenhouse gases emissions, and some emissions from industry. The plan investigates the actions needed to improve the current state so as to make carbon neutrality achievable by 2035.

In addition to environmental sustainability, the Sustainable Growth Programme for Finland: Recovery and Resilience Plan was also published in 2021, aiming to reduce greenhouse gas emissions, increase productivity, raise the employment rate, ensure quicker access to care, and equality. The Sustainable Growth Programme will focus on four pillars:

(A) A green transition will support structural adjustment of the economy and underpin a carbon-neutral welfare society:

Green transition solutions will be accelerated to facilitate significant reductions in emissions in Finland and elsewhere to support national targets for carbon neutrality and the circular economy. This will enable future sustainable growth as well. The aim is to make Finland a global leader in the fields of hydrogen and circular economy, high added value bioproducts, zero-emission energy systems and other climate and environmental solutions; to improve energy efficiency; and to accelerate the transition to fossil-free transport and heating. Actions to attain these targets include mobilizing the widest possible range of investments in tangible and intangible assets that efficiently promote green transition and bring comprehensive solutions to the market.

(B) Digitalization and a digital economy will strengthen productivity and make services available to all:

Digitalization and the data economy will be boosted in private and public services so as to improve cost-efficiency and productivity and to make safe services for good everyday life available to everyone across the country. The targets are to create a competitive operating environment for businesses and to turn Finland into a world-class producer of data-driven services for digital societies, together with secure solutions for these services, including solutions to promote the digitalization of transport. The digital leap in society at large will be encouraged through actions targeted at accelerating technology and data investments.

(C) Raising the employment rate and skill levels will accelerate sustainable growth:

Raising the employment rate will be boosted with a client-oriented reform of services and by leveraging digitalization, promoting employment of persons with partial work ability, streamlining work-based immigration, enhancing integration and improving wellbeing at work. Long-term growth will be promoted by upskilling and by introducing opportunities for continuous learning. R&D intensity will be raised in order to accelerate growth. Renewal, recovery and sustainable growth in sectors most affected by the pandemic crisis will also be accelerated by leveraging innovations and research findings in the creative economy and in the events industry.

(D) Access to health and social services will be improved and their cost-effectiveness enhanced:

Deficits will be reduced by reforming operating models and by introducing new digital services. Access to treatment will be improved by introducing new operating procedures. This will contribute to the attainment of the targets of the health and social services reform. The target is to make services available to everyone and to reform them from the perspective of the individual and cost-effectively.

G. China

Every once in five years, the Chinese government sets economic visions and development goals for the next five years. This five-year plan significantly affects the country's economic transformation and capital market changes. In March 2021, the 14th Five-Year Plan was approved at the 4th meeting of the 13th National People's Congress, incorporating long-range objectives that will be achieved over the next 15 years through to 2035. These objectives include the following: further increase economic aggregate and urban/rural per capita income; develop key/core technologies to be at the forefront of innovation-oriented countries; realize a modern economic system of new industrialization, informatization, urbanization, and modernization of the agricultural sector; popularize green production and green lifestyle, steadily reduce carbon emissions after carbon peaking, and fundamentally improve the ecological environment; form new plans for opening up externally and significantly strengthen participation in international economic cooperation and new advantages for competition; increase per-capital GDP to the levels of moderately developed countries and significantly enlarge moderate-income groups.

The ten development objectives during the 14th Five-Year Plan period(2021-2025) are as follows: Proposals for the average annual growth of GDP will be maintained in a reasonable range based on the situation each year; growth of total labor productivity will exceed the growth of GDP; increase the urbanization rate of the permanent resident population by 2025 to 65%; the R&D expenditure of society as a whole will increase by more than 7% annually and strive to make the intensity of investment higher than the actual investment during the period of the "13th Five-Year Plan" period; the added value of core digital economy industries will account for 10% of GDP by 2025; the growth of per capita disposable income of residents will be basically synchronized with the growth of GDP; urban surveyed unemployment rate will be maintained below 5.5%; energy consumption and carbon dioxide emissions per unit of GDP will be reduced by 13.5% and 18%, respectively over a 5-year period; proportion of days with good air quality in cities at prefecture level and above must reach 87.5% by 2025; and comprehensive grain production capacity and comprehensive energy production capacity must be 650 million and 4.6 billion metric tons of standard coal equivalent, respectively.

The Chinese government proposed five policy directions to cultivate new driving forces for its economic development and enhance the smoothness of economic operations. The five directions are scientific research and innovation, market reform, green development, human resources, and balanced social development. Actions for scientific research and innovation include the following: raise the proportion of basic research funding as a portion of R&D funding to over 8%; support the formation of international S&T innovation centers in Beijing, Shanghai, and the Guangdong-Hong Kong-Macau Greater Bay Area, and build comprehensive national science centers in Huairou in Beijing, Zhangjiang in Shanghai, the Greater Bay Area, and Hefei in Anhui, the Greater Bay Area, and Hefei in Anhui; cultivate advanced manufacturing clusters and promote the innovative development of industries such as ICs, aerospace, shipping and maritime engineering equipment, robotics, advanced rail transit equipment, advanced power equipment, engineering machinery, high-end computer numerical control (CNC) machines, and medical and health equipment; promote the integration, clustering, and ecosystem-driven development of strategic emerging industries, and raise the added value of strategic emerging industries to more than 17% of GDP; and develop technology and data factor of production markets. Key actions for green development include the following: accelerate the development of non-fossil energy and increase the proportion of non-fossil energy in total energy consumption to about 20%; formulate an action plan for carbon dioxide peaking before 2030; and focus our efforts on achieving carbon neutrality by 2060 and adopt more forceful policies and measures.

H. Japan

In June 2020, the Japanese government substantially amended the Science and Technology Basic Law, renaming it as the Science, Technology and Innovation Basic Law. The new name came into force as of April 2021. The amendment aimed to add innovation, humanities and social sciences as part of the nation's S&T development goals. Since 1996, the Cabinet Office of Japan has been formulating the Science, Technology and Innovation Basic Plan every five years based on the Science and Technology Basic Law. Given changes inside and outside of Japan over the past five years, the 6th Science, Technology and Innovation Basic Plan will be focused on responses to the increasingly tense confrontation between the U.S. and China and a new world order, global problems such as climate change, and the structural reform of domestic systems in response to the COVID-19 pandemic. Through this plan, the government aims to bring diverse well-being to every single Japanese national and global citizen. The 6th Basic Plan promotes the following three policy directions and actions:

(A) Transformation into a sustainable and resilient society that ensures the safety and security of the people; this is achieved by the following actions: Create new value through the fusion of cyber space and physical space; promote social change and continuous innovation to overcome global issues; build a resilient, safe, and secure society; form an innovation ecosystem that is the foundation for creating new industries that share value; undergo urban and regional development (development of smart cities) utilizing emerging technologies such as ICT; and promote research and development and social implementation to solve various social problems and utilization of the convergence of knowledge.

(B) Developing frontiers of knowledge and strengthening research capabilities as sources of value creation; this is achieved by the following actions: Rebuild the environment to produce diverse and outstanding research; construct new research systems to promote open science and data-driven research; and promote university reform and expand functions for strategic management.

(C) Education and human resource development to realize diverse happiness (well-being) and challenges for each individual; this is achieved by the following actions: Strengthen the ability to inquire and explore starting from the elementary and secondary education stage; enhance problem-finding and problem-solving learning; develop individualistic university systems at the higher education stage to satisfy the different needs of individuals; provide a lifelong learning environment for Japanese citizens to develop new career paths; and enhance recurrent education and the mobility of human resources.

Mobile communications system has evolved from an infrastructure to an essential service in the everyday life of people. In light of this trend, the Ministry of Internal Affairs and Communications in Japan published the Beyond 5G Promotion Strategy: Roadmap towards 6G in June 2020, presenting mid- and long-term promotion strategies for Beyond 5G (B5G otherwise known as 6G) the next generation communications system in 2030.

The B5G Promotion Strategy is aimed at strengthening the international competitiveness of Japan by acquiring 30% of share in the global market and cementing the global presence of B5G devices and platforms. To achieve these objectives, Japan must become a cornerstone of the global open innovation ecosystem in the development and usage of Beyond 5G. For this reason, the Ministry of Internal Affairs and Communications established a cross-department Beyond 5G Strategic Promotion Task Force, which will promote strategic planning in cooperation with the Council for Science, Technology and Innovation (CSTI), the IT Strategy Headquarters, and the Cybersecurity Strategic Headquarters. The task force will compile and publish a progress report every year. Based on the three basic principles of global first, building ecosystems that drive innovation, and intensification of resources, three sub-strategies on R&D, intellectual property and standardization, and deployment were proposed to strengthen the international cooperation of the government and private sectors.

Japan has proposed developing disruptive and highly influential innovative technologies to address major social problems including aging populations, declining birth rate, and climate change. In 2018, the CSTI acknowledged the necessity of the Moonshot Research and Development Program. After calling for plans and recommendations for the program in 2019, the Council established, in 2020, seven goals to be achieved by 2050 through the Moonshot Research and Development Program: Realization of a society in which human beings can be free from limitations of body, brain, space, and time; realization of ultra-early disease prediction and intervention; realization of AI robots that autonomously learn, adapt to their environment, evolve in intelligence and act alongside human beings; realization of sustainable resource circulation to recover the global environment; creation of the industry that enables sustainable global food supply by exploiting unused biological resources; realization of a fault-tolerant universal quantum computer that will revolutionize economy, industry, and security; and realization of sustainable care systems to overcome major diseases by 2040, for enjoying one's life with relief and release from health concerns until 100 years old.

A key feature of the Moonshot R&D Program lies in its ability to address societal issues that are difficult to tackle but will have profound impact once resolved. Ambitious goals (i.e., Moonshot goals) were jointly established by CSTI and the Headquarters for Healthcare Policy. On the premise that failure is permitted, top researchers from around the world are invited and encouraged to propose revolutionary research projects that maximize Japan's basic research capabilities and realize the Moonshot goals. Meanwhile, the Program will be flexibly managed and revised in a snowball manner to keep pace with global progress in R&D development and to build a world-leading R&D system. In addition, the commercialization of the R&D results will be facilitated by including humanities and social science researchers in the program to address ethical and social issues as well as issues concerning the legal system during the R&D stage.

Various actions have been taken during autumn and winter of 2020. R&D organizations in Japan, including Japan Science and Technology Agency, New Energy and Industrial Technology Development Organization, Bio-oriented Technology Research Advancement Institution, and Agency for Medical Research and Development, have launched 5–10-year research projects. The objectives of the Moonshot R&D Program are based on the goals of securing national interest and future industrial competitiveness. Seven Moonshot goals aimed at creating a future of possibilities through technology were established to realize human well-being and tackle potential social, environmental, and economic problems, thereby cementing Japan's foundation for development.

I. South Korea

Since 1994, South Korea has been engaging in Science and Technology Foresight projects to prepare for changes in the future. In 2017, the Ministry of Science and ICT and Korea Institute of S&T Evaluation and Planning jointly released the 5th Science and Technology Foresight report, which identified future technologies that are solutions to future societal problems and introduced a tipping point analysis. The tipping point of a technology is the time at which the technology is rapidly diffused throughout society. Moving past a foresight function with a task-oriented focus, the report can be summarized by three broad objectives:

(A) To predict the future society considering the internal and external environmental changes, and to predict and analyze the development of future technologies around the time axis of 2040.

(B) To contribute basic data on policy establishment needed for the 4th Master Plan for Science and Technology (2018–2022), including timing of technology realization, importance, and way to realize the future technologies, and more importantly reflecting the socio-economic demands of future society.

(C) To predict the tipping point of technology in terms of social spread, focusing on major innovative technologies.

The 5th Science and Technology Foresight defined future technologies that will have a significant impact on science, technology, society and economy in South Korea, identifying the name and definition of 267 future technologies that are expected to emerge by 2040. The technologies are classified into six major groups: social infrastructure technology, ecosystem and environmentfriendly technology, transportation and robotics technology, medical and life technology, manufacturing and convergence technology and information and communication technology. Looking ahead to the importance of technology to the society in 2040, the report took an inventory of the competitiveness of South Korea's future technologies and its gap with the international community, providing a basis for the formulation of long-term development strategies and resource allocation for the future. It also suggested necessary items for researchers to check the readiness of the country's technologies and future preparation and encourage interest in and preparation for the upcoming future in ordinary citizens.

The Ministry of Science and ICT (MSIT) of South Korea presented the "2023 Government R&D Investment Direction and Standards (draft)" on March 8, 2023, which revealed that the South Korean government will focus its investments in 2023 on nurturing the nation's ten critical and emerging technologies, achieving carbon neutrality by 2050, and digital transition, with the aim to take up a dominant position amid global tech competition. Investment will also be made to nurture scientists and engineers, create a research-centric basic science research environment, and enhance tech capabilities of different regions and small and medium-sized companies. Other support measures include the setup of the R&D support platform and improvement of the R&D investment system that connects innovation leaders from the public and the private sectors.

J. Singapore

Since its first National Technology Plan in 1995 to develop a knowledge-based, innovation-driven society and economy, Singapore has aimed to develop high-technology activities that would move the country up the economic value chain and build a strong base of scientists, engineers and technologists who would help to drive economic and enterprise transformation. In 2010, Singapore's R&D strategy was expanded to span Research, Innovation and Enterprise (RIE). The RIE2015 and RIE2020 plans included translation, commercialization and innovation strategies to tap on the growing pipeline of promising research outputs and support Singaporean enterprises.

Climate change and COVID-19 have brought about unprecedented disruption to global economies and societies. In response, the National Research Foundation of Singapore published the RIE2025 Plan in December 2020, which is the seventh national technology plan that is refreshed every five years, in order to tackle a broader spectrum of national needs, enhance Singapore's competitive advantage in the long-term, and anchor its position as a Global-Asia node of technology, innovation and enterprise. Under the previous RIE plans, the RIE2025 plan will be organized along four strategic domains: Manufacturing, Trade and Connectivity (MTC), Human Health and Potential (HHP), Urban Solutions and Sustainability (USS), and Smart Nation and Digital Economy (SNDE), and supported by three cross-cutting horizontals: Academic research, manpower, and innovation and enterprise in order to promote excellence in academic research, nurture a strong research talent pipeline, and develop a dynamic national innovation system.

2.2. Resources Available to and Effectiveness of S&T Development in Taiwan

2.2.1 Funding

(1) S&T budgets allocated by the central government

The central government allocated total budgets of NT$114.08 billion in 2021 for S&T development. Table 2-1 shows the amount of S&T budgets allocated to each government agency. In 2021, 38.2% (the highest) of the S&T budget was allocated to the Ministry of Science and Technology (currently known as NSTC), followed by 29.8%, 10.23%, and 21.77% to the Ministry of Economic Affairs, Academia Sinica, and other ministerial departments, respectively.

Table 2-1. S&T budgets allocated to government agencies in 2018–2021 (including special budgets for frontier research)

Unit: NT$1,000

Agency	2018	2019	2020	2021
Ministry of Science and Technology (NSTC)	42,765,454	47,716,755	49,021,705	43,583,882
Science and Technology Development Fund	3,055,596	2,084,055	2,146,724	1,674,144
Ministry of Economic Affairs	31,430,364	30,398,493	30,385,070	33,992,968
Academia Sinica	11,674,471	11,082,397	11,282,344	11,673,001
Ministry of Health and Welfare	4,998,637	4,716,853	4,769,501	4,494,895
Council of Agriculture	4,425,968	4,325,933	4,423,172	4,492,213
Ministry of Education	4,750,994	4,482,181	3,991,381	2,243,148
Ministry of Transportation and Communications	1,292,497	1,187,431	1,128,484	2,221,009
National Development Council	996,899	2,009,639	2,099,712	993,097
Ministry of the Interior	2,214,392	977,329	827,529	1,328,017
Ministry of Culture	1,884,372	2,297,187	2,122,727	952,668
Atomic Energy Council	740,983	501,143	493,238	641,231
National Communications Commission	705,035	771,032	881,931	3,173,799
Ministry of Justice	289,210	259,662	270,471	232,739
Ministry of Labor	223,331	208,598	244,660	242,078
Ministry of Finance	845,178	249,611	208,051	450,189
Environmental Protection Administration	393,268	147,647	163,451	349,550
Ministry of National Defense	176,100	158,900	169,000	143,380
Ocean Affairs Council	-	129,820	163,583	112,437
Council of Indigenous Peoples	192,000	105,680	103,917	279,138
Directorate-General of Personnel Administration	56,232	57,970	61,982	88,929
Taiwan Transportation Safety Board (Aviation Safety Council)	8,479	8,241	38,399	35,177
Board of Science and Technology	40,293	39,793	39,793	39,293

Agency	2018	2019	2020	2021
Financial Supervisory Commission	15,270	34,239	37,001	24,789
Directorate-General of Budget, Accounting and Statistics	15,622	15,072	25,713	-
Executive Yuan Department of Information Management	31,400	27,866	22,082	11,100
National Palace Museum	121,538	7,222	12,230	108,100
Department of Cybersecurity	378,423	1,035,000	985,599	409,000
National Audit Office	-	3,053	3,150	-
Ministry of Foreign Affairs	-	1,900	1,856	-
Public Construction Commission	5,126	-	-	12,100
Hakka Affairs Council		-	-	42,500
Civil Service Protection and Training Commission	2,600	-	-	-
Academia Historia	45,850	-	-	39,200
Total	113,775,582	115,040,702	116,124,456	114,083,771

Data source: NSTC.

(2) Analysis of global R&D input

To remain technologically advanced amidst challenges from new global trends (climate change, geopolitical conflicts, US–China conflict, and Russian invasion of Ukraine, among other environmental factors) and the rise of new future technologies, a continuous stream of funding must be ensured to support R&D and innovation. In addition, an analysis of workforce engaged in emerging technological activities and R&D investments of various countries sheds light on the level of innovation and R&D profile of each country.

Continuous R&D and creation and the development and accumulation of new knowledge, new methods, and new products can enable an industry to acquire stronger innovation capability and drive the growth and value of the nation's economy, all the while increasing national income and benefits, which in turn continuously enhance the nation’s competitive advantages. Hence, R&D and innovation are critical to not only the development of industries and the economy, but also a country’s international competitiveness and global presence. When the world was plagued by the outbreak of COVID-19, regional geopolitical turmoil, and technological war among major economies, all countries were heavily invested in R&D and innovation to support the research and development of innovative technologies and commit to becoming leaders of technological innovation.

R&D investments have therefore garnered much attention around the world, a trend highlighted by the EU’s Europe 2020 strategy, which aims to invest at least 3% of the EU’s GDP in R&D.

According to the 2022 data published in the OECD Main Science and Technology Indicators (MSTI) database, OECD economies continued to increase investments in R&D in 2020 despite the sharp decline in economic activity due to the COVID-19 pandemic. Real growth in R&D in the OECD area in 2020 was primarily driven by growth in the United States at 5%, in contrast with R&D expenditures in Germany, which declined by 1.5%. China’s reported R&D expenditure grew by 11% in 2020 (see Figure 2-1). When R&D expenditure was adjusted for differences in purchasing power parity (PPP) by country and region, China’s R&D expenditure gap with respect to the United States remained stable, with China’s R&D expenditure at close to 81% of that of the United States.

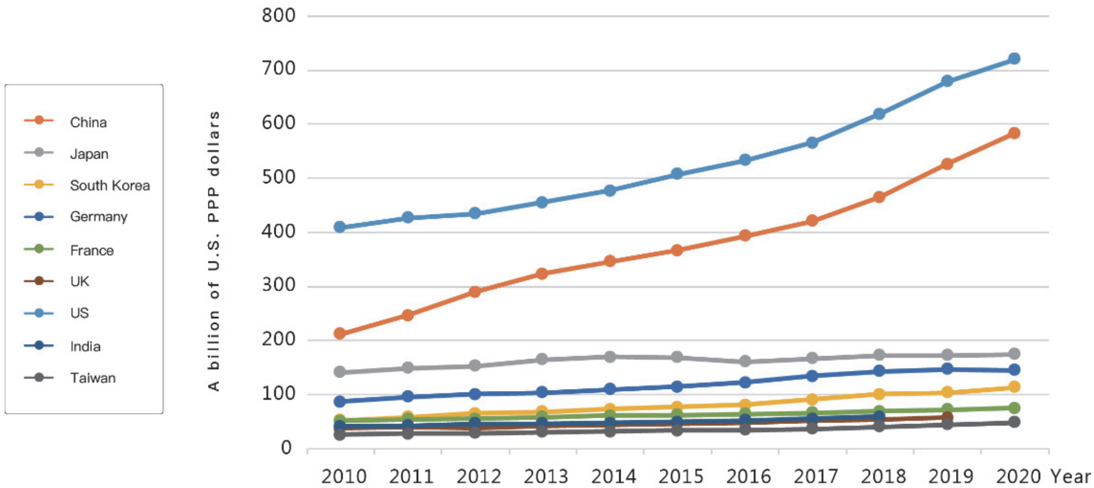

Figure 2-1. Total expenditures on R&D by each country during 2010–2020

Data source: OECD Main Science and Technology Indicators 2022 (downloaded in December 2022) and compiled by the Science & Technology Policy Research and Information Center (STPI).

R&D intensity has been used an international measure of a country's innovation capability to account for the different scales and R&D focuses of various economies. According to a 2022 report by the National Science Foundation (NSF), smaller economies including Israel, South Korea, and Taiwan had higher R&D intensities than did the United States, as shown in Figure 2-2. The United States have made significant R&D investments; however, its R&D intensity has fluctuated around 2.7%–3.45% in recent years, whereas China's R&D intensity grew significantly from 1.7% in 2010 to 2.4% in 2020. South Korea also actively strengthened its R&D investments, which increased its R&D intensity from 3.3% to 4.8% over the past ten years. Taiwan also saw continuous growth in recent years (from 2.8% to 3.6%). The percentage of gross domestic expenditure on R&D (GERD) financed by the government, as shown in Figure 2-3, dropped from 27.5% in 2010 to 16.8% in 2020, highlighting the fact that the R&D expenditure expended by the Taiwanese government has been consistently below the average of OECD countries.

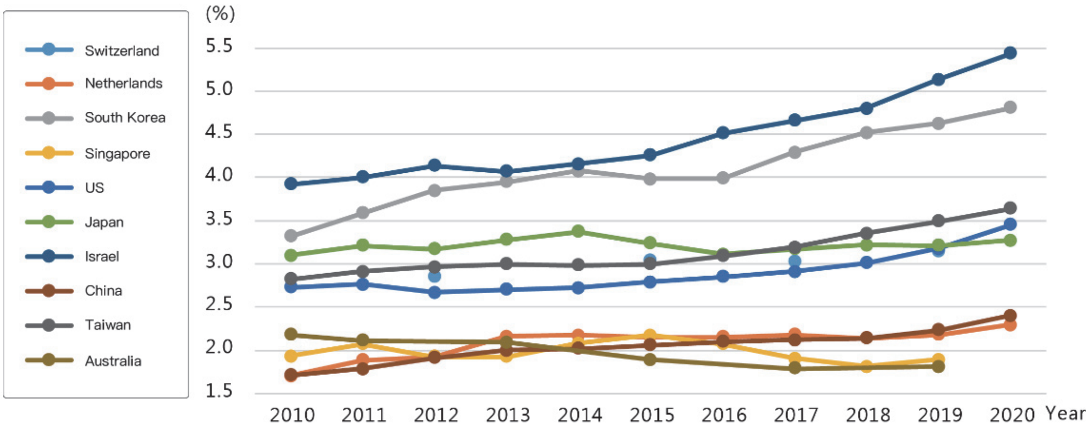

Figure 2-2. The R&D intensities of major countries during 2010–2020

Data source: OECD Main Science and Technology Indicators 2022 (downloaded in December 2022) and compiled by STPI.

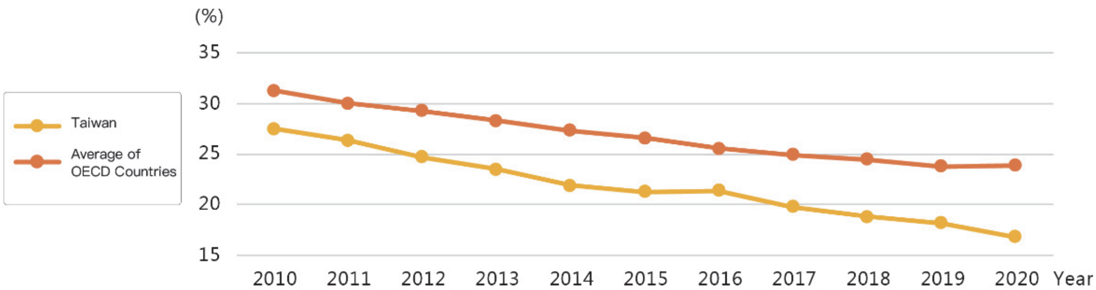

Figure 2-3. Percentage of GERD financed by government in Taiwan and OECD during 2010–2020

Data source: OECD Main Science and Technology Indicators 2022 (downloaded in December 2022) and compiled by STPI.

Further breakdown of expenditures on R&D in each country (Figure 2-4) shows that expenditures on basic research and development as a percentage of GERD gradually declined for Taiwan over the past 10 years, reaching only 7% in 2020, which is substantially lower than those for the United States (15%), South Korea (14.45%), and Japan (12.29%) and indicates further room for improvement in terms of Taiwan's basic R&D investments. Expenditures on R&D declined for Taiwan primarily because the business sector, which is the main R&D performer in Taiwan, is not committed to basic research. According to Figure 2-5, the non-government sector in Taiwan has a lower share of R&D expenditures devoted to basic research in 2020 (1.7%) compared with the non-government sector in other countries such as the United States (10.7%), Netherlands in 2019 (16.2%), and Israel (5.6%), although the Taiwan government's R&D expenditures spent on basic research (33.3%) are high compared to numerous other countries (Figure 2-6).

The non-government sector in Taiwan has a lower share of R&D expenditures devoted to basic research mainly because this sector is predominantly composed of small and medium enterprises (SMEs) and original equipment manufacturers (OEMs), whose limited funding renders them unable to have the spending power and foresight to support basic research. In other words, as long as industries have not yet fully and successfully transformed in the current trend of digital transformation, the Taiwan government remains responsible for making up the shortage of private investments in various industrial and national basic research.

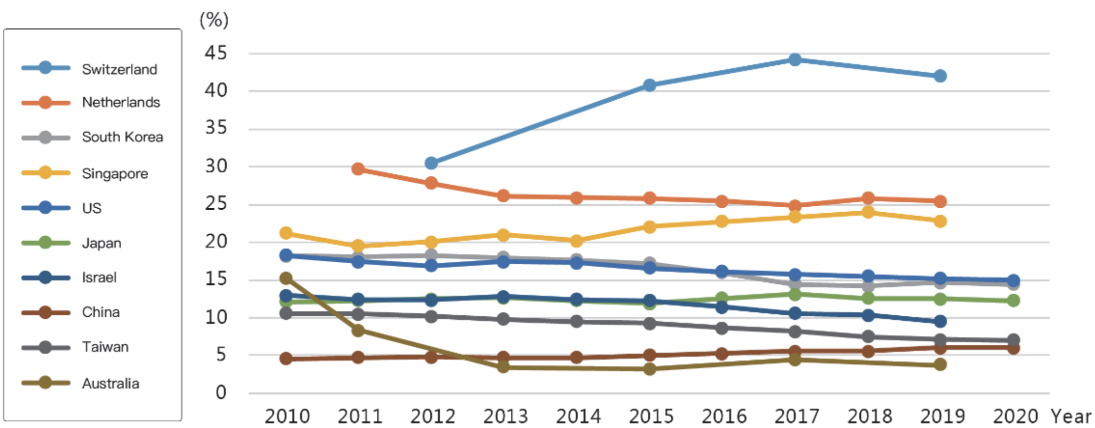

Figure 2-4. Gross expenditures on basic research as a percentage of GERD during 2010–2020

Data source: OECD Main Science and Technology Indicators 2022 (downloaded in December 2022) and compiled by STPI.

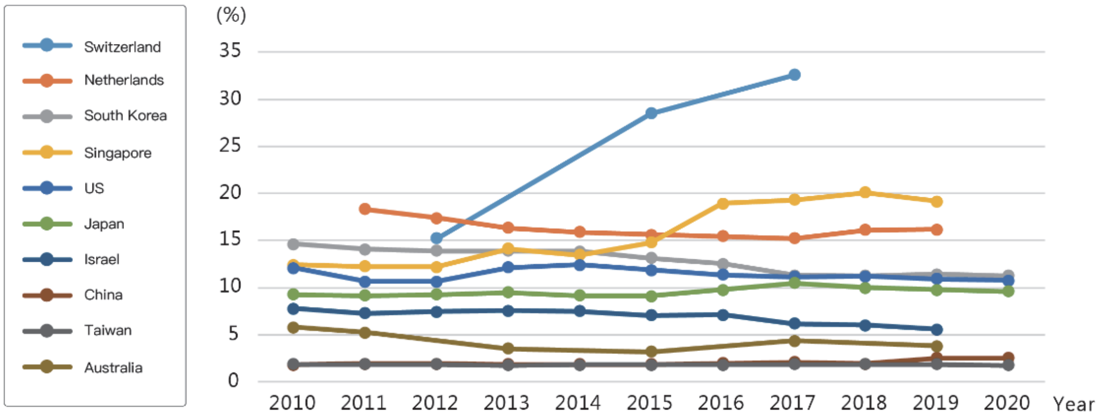

Figure 2-5. Gross expenditures on basic research by non-government sector as a percentage of GERD by that sector during 2010–2020

Data source: OECD Main Science and Technology Indicators 2022 (downloaded in December 2022) and calculated by STPI.

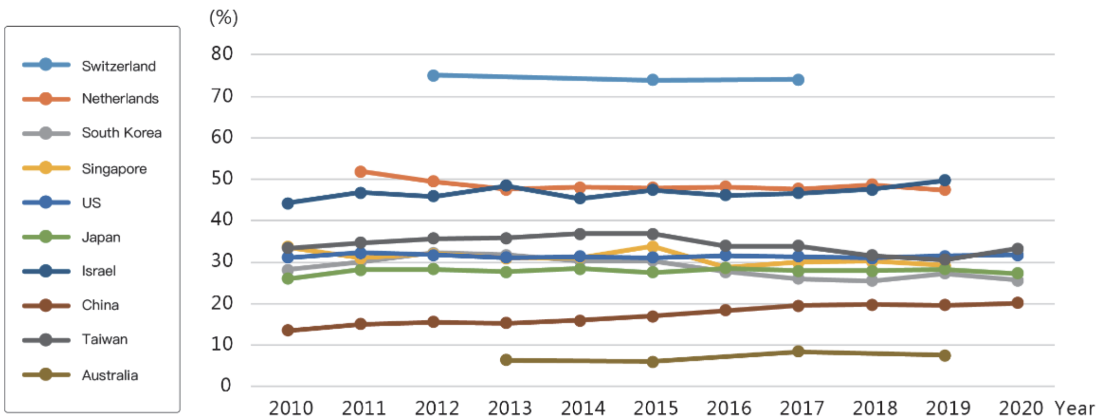

Figure 2-6. Gross expenditures on basic research by the government sector as a percentage of GERD by the government during 2010–2020

Data source: OECD Main Science and Technology Indicators 2022 (downloaded in December 2022) and calculated by STPI.

2.2.2 Human Resources

Enrollment rates for universities and colleges in Taiwan have dropped dramatically in recent years, although the number of students studying a Master's or doctoral degree has been increasing slowly to 1,112,161 as of academic year 2021, with most of the students studying degrees related to S&T (Table 2-2).

Table 2-2. Statistics on students in Taiwan by subject category in the last four years

Unit: People

Student	Subject Category	Academic Year 2018	Academic Year 2019	Academic Year 2020	Academic Year 2021
PhD Students	Humanities	22.07%	22.15%	21.67%	21.49%
	Social Science	18.76%	18.74%	18.97%	18.91%
	S&T	59.17%	59.11%	59.36%	59.59%
	Total	**28,167**	**28,510**	**28,555**	**28,907**
Master's Students	Humanities	20.61%	20.53%	20.64%	20.71%
	Social Science	34.19%	34.16%	33.91%	33.52%
	S&T	45.20%	45.31%	45.44%	45.77%
	Total	**168,092**	**168,203**	**168,974**	**171,779**
Undergraduate Students	Humanities	20.26%	20.38%	20.28%	20.97%
	Social Science	38.85%	38.35%	38.03%	36.96%
	S&T	40.89%	41.28%	41.70%	42.07%
	Total	**961,905**	**932,518**	**917,197**	**911,475**
Grand Total		1,158,164	1,129,231	1,114,726	1,112,161

Data source: Department of Statistics, Ministry of Education.

Note: 1. Humanities category includes education, arts, humanities, and others (including sports); 2. Social science category includes economics and social psychology, business and administration, law, tourism services, mass communications, and home economics (excluding food and nutrition); 3. S&T category includes natural science, mathematics and computer, medicine and health, industrial arts, engineering, architecture and urban planning, agriculture/forestry/fisheries/livestock, transportation and telecommunication, and food and nutrition.

The total number of higher education graduates in Taiwan dropped from 286,687 in 2018 to 266,696 in 2020, as shown in Table 2-3. Due to aging population, dwindling birth rate in Taiwan, and negative growth in number of bachelor's degree graduates, the number of graduates as a whole in the academic year of 2020 decreased by 1.0% compared with 2019; however, PhD graduates exhibited an upward trend, increasing by 5.3% compared with 2019.

Table 2-3. Number of higher education graduates in Taiwan in the past three years

Unit: People

Student	Subject Category	Academic Year 2018	Academic Year 2019	Academic Year 2020
PhD Students	Humanities	627	659	670
	Social Science	529	549	591
	S&T	2,150	2,160	2,296
	Total	**3,306**	**3,368**	**3,557**
Master’s Students	Humanities	7,837	7,571	7,633
	Social Science	18,587	18,602	18,545
	S&T	27,824	27,257	28,220
	Total	**54,248**	**53,430**	**54,398**
Undergraduate Students	Humanities	43,972	41,827	41,418
	Social Science	92,099	84,316	81,618
	S&T	93,062	86,720	85,705
	Total	**229,133**	**212,863**	**208,741**
Grand Total		286,687	269,661	266,696

Data source: Department of Statistics, Ministry of Education.

Note: 1. Humanities category includes education, arts, humanities, and others (including sports education); 2. Social science category includes economics and social psychology, business and administration, law, tourism services, mass communications, and home economics (excluding food and nutrition); 3. S&T category includes natural science, mathematics and computer, medicine and health, industrial arts, engineering, architecture and urban planning, agriculture/forestry/fisheries/livestock, transportation and telecommunication, and food and nutrition.

R&D workforce in Taiwan comprised researchers, technicians, and supporting staff, all three of which exhibited a growth trend in the past three years with technicians presenting the greatest extent of growth, accounting for 36.5% of the entire R&D workforce in 2020. The percentage of researchers and supporting staff has been stable, as shown in Table 2-4.

The intensity of R&D personnel in Taiwan during the past three years presented an upward trend, reaching 14.2 person-year in 2020. In addition, Taiwan has lower total number of researchers in full-time equivalent per thousand employment compared with Finland, Sweden, and South Korea, but higher total researchers compared with the United States, France, Canada, Japan, Germany, Russia, United Kingdom, and China, as indicated in Figure 2-7. Female researchers increased from 33,087 person-year in 2018 to 35,663 person-year in 2020, exhibiting stable growth trend. However, number of female researchers as a percentage of total researchers did not change significantly (Table 2-4).

Table 2-4. R&D workforce in Taiwan during the past three years

Unit: Full-time equivalents, %

Item	2018	2019	2020
R&D Workforce	262,307	271,579	279,647
Researchers	153,998	159,160	163,536
As a percentage of R&D workforce	58.7%	58.6%	58.5%
Technicians	94,862	98,725	101,981
As a percentage of R&D workforce	36.2%	36.4%	36.5%
Supporting Staff	13,446	13,694	14,130
As a percentage of R&D workforce	5.1%	5.0%	5.1%
Total researchers per thousand total employment	13.5	13.8	14.2
Female researchers as a percentage of total researchers in Taiwan	33,087 21.49%	34,269 21.53%	35,663 21.81%

Data source: 2021 Indicators of Science and Technology, NSTC (formerly MOST).

Note: R&D workforce is measured in full-time equivalents (FTE), which converts the number of people engaged in R&D work to the number of people engaged in full-time R&D work and is expressed as person-year.

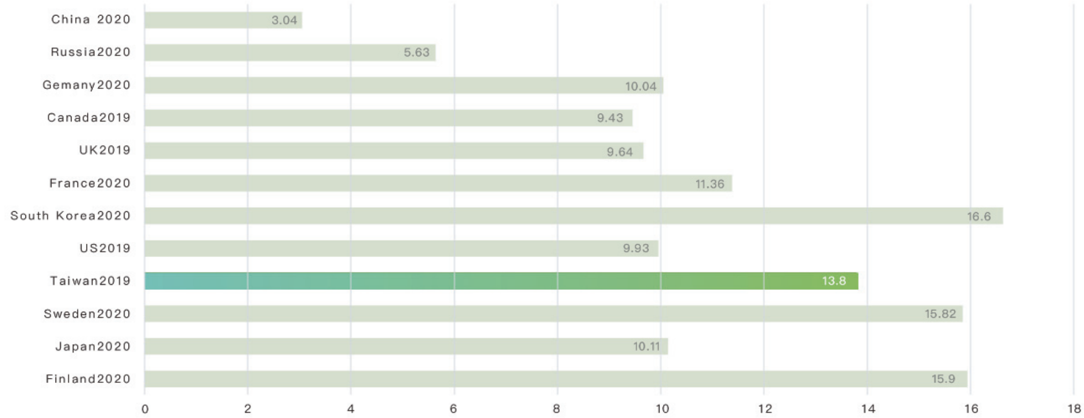

Figure 2-7. Total researchers per thousand total employment in each country

Data source:

1. For Taiwan: 2021 Indicators of Science and Technology, NSTC (formerly MOST).
2. For other countries: Main Science and Technology Indicators (Total researchers per thousand total employment), 2022/10, OECD.

R&D workforce in performing sectors: The business enterprise sector had the largest R&D workforce over the years, followed by the higher education sector and government sector. The R&D workforce in the business enterprise sector grew by 7.15% from 203,456 people in 2018 to 291,112 people in 2020. The R&D workforce in the higher education sector grew by 0.66% from 31,896 people in 2018 to 32,107 people in 2020. The R&D workforce in the government sector grew by 5.43% from 26,411 people in 2018 to 27,928 people in 2020. The R&D workforce in the private non-profit sector decreased from 544 people in 2018 to 501 people in 2020. The percentage of researchers has been the highest throughout the years, followed by technicians, and the percentage of supporting staff was the lowest, as shown in Table 2-5. In 2020, the R&D workforce in the higher education sector comprised mostly researchers at 90.3%; technicians formed the majority of the R&D workforce in the business enterprise sector at 41.6%; the percentage of supporting staff was lower than 22% in all sectors

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Table 2-5. R&D workforce in Taiwan during the past three years (by performing sector)

Performing Sector	Workforce Category	2018	2019	2020
Business Enterprise	Researcher	53.7%	53.8%	53.9%
	Technician	41.5%	41.6%	41.6%
	Supporting Staff	4.7%	4.6%	4.5%
	Total	**203,456**	**210,576**	**219,112**
Government	Researcher	59.4%	58.8%	57.8%
	Technician	30.8%	31.3%	31.2%
	Supporting Staff	9.8%	9.9%	11.0%
	Total	**26,411**	**28,612**	**27,928**
Higher Education	Researcher	90.2%	90.3%	90.3%
	Technician	6.4%	6.4%	6.4%
	Supporting Staff	3.4%	3.3%	3.3%
	Total	**31,896**	**31,871**	**32,107**
Private Non-profit	Researcher	49.2%	46.7%	44.5%
	Technician	31.2%	35.3%	34.0%
	Supporting Staff	19.6%	18.0%	21.4%
	Total	**544**	**520**	**501**

Data source: 2021 Indicators of Science and Technology, NSTC (formerly MOST).

Academic qualifications of researchers in Taiwan: The number of R&D personnel in Taiwan has been increasing in the past three years. The number of researchers with a bachelor’s degree increased slightly, accounting for about 27% of researchers in Taiwan. The number of researchers with Master’s degree has been stable, accounting for more than half of researchers in Taiwan. The number of researchers with doctoral degree exhibited minor increase (Table 2-6).

Table 2-6. Academic qualifications of researchers in Taiwan in the past three years

Qualification	2018	2019	2020
Doctorate (no. of people) As a percentage of researchers	27,096 17.6%	27,349 17.2%	27,870 17.0%
Master (no. of people) As a percentage of researchers	85,892 55.8%	88,864 55.8%	91,256 55.8%
Bachelor (no. of people) As a percentage of researchers	41,010 26.6%	42,947 27.0%	44,410 27.2%
Total Researchers	153,998	159,160	163,536

Data source: 2021 Indicators of Science and Technology, NSTC (formerly MOST).

2.2.3 Competitiveness Analysis

Taiwan emerged as the seventh most competitive economy, out of the 63 economies, in the 2022 World Competitiveness Yearbook released by the International Institute for Management Development (IMD). The rankings are based on 255 criteria, categorized into 20 sub-categories under four factors of economic performance, government efficiency, business efficiency, and infrastructure.

See Table 2-7 for the rankings of major countries in 2022 in the four factors and rankings under each sub-category of the Infrastructure factor (number in parenthesis represents Taiwan's ranking in 2021 for comparison purpose).

Table 2-7. Rankings of major countries in the IMD 2022 World Competitiveness Yearbook

Category	US	Hong Kong	Singapore	Netherlands	Switzerland	China	Germany	**Taiwan**	UK	Israel	Japan	South Korea
Overall Ranking	10	5	3	6	2	17	15	**7(8)**	23	25	34	27
1. Economic Performance	3	15	2	19	30	4	5	**11(6)**	23	36	20	22
2. Government Efficiency	27	2	4	12	1	29	21	**8(8)**	26	32	39	36
3. Business Efficiency	12	7	9	3	4	15	21	**6(7)**	28	27	51	33
4. Infrastructure	7	14	12	5	1	21	9	**13(14)**	18	17	22	16
(1) Basic Infrastructure	18	11	43	10	5	14	24	**37(38)**	31	35	38	16
(2) Technological Infrastructure	**11**	**7**	**1**	**4**	**6**	**12**	**33**	9(10)	**18**	**10**	**42**	**19**
(3) Scientific Infrastructure	**1**	**23**	**16**	**11**	**4**	**9**	**2**	6(6)	**14**	**5**	**8**	**3**
(4) Health and Environment	22	18	25	15	1	35	6	**26(24)**	12	33	9	31
(5) Education	14	13	6	11	1	28	23	**16(16)**	21	22	38	29

Data source: IMD World Competitiveness Yearbook 2022, organized by STPI.

Taiwan ranked 7th among 63 countries in the IMD 2022 World Competitiveness Yearbook, moving up rankings four years in a row. The nation's seventh-place ranking is its highest in the yearbook since 2013[1]. In terms of individual indicators, Taiwan improved in both business efficiency and infrastructure compared with previous year, remained unchanged in government efficiency, but fell five spots from 6th to 11th in economic performance, a consequence of the nationwide level 3 COVID-19 alert in 2021.

Taiwan showed improvement in 7 of the 20 sub-categories compared to last year, 5 of which were ranked in the top 10, including Tax Policy (6th) and Institutional Framework (8th) under the Government Efficiency factor, a result reflecting the recognition of the government's commitment to building a friendly business environment, IMD said. In the Business Efficiency factor, the nation improved 5 spots in Productivity & Efficiency (8th), which IMD attributed to the growth of GDP (PPP) for employees, and 3 spots in Finance (8th), which IMD attributed to the COVID-19 pandemic speeding up the use of electronic and online transactions instead of cash transactions. In the Infrastructure factor, Taiwan moved up 1 spot due to Technological Infrastructure (9th), which IMD explained to be the cause of higher value regarding R&D workforce and digital access in Taiwan.

An analysis of the performance of Taiwan in the IMD 2022 World Competitiveness Yearbook based on the value chain of S&T development (Figure 2-8) reveals that Taiwan performed outstandingly in high-tech exports (3rd) but fell behind in ICT service exports (25th). However, the nation requires improvement in two indicators: the availability of digital/technological skills and attracting foreign highly-skilled personnel to Taiwan. These results show that Taiwan possesses a strong R&D workforce and innovation capability, but its incentive for attracting skilled researchers warrants further improvement.

[1] World Competitiveness Yearbook (2022), URL: https://imd.cld.bz/IMD-World-Competitiveness-Booklet-2022/34/.

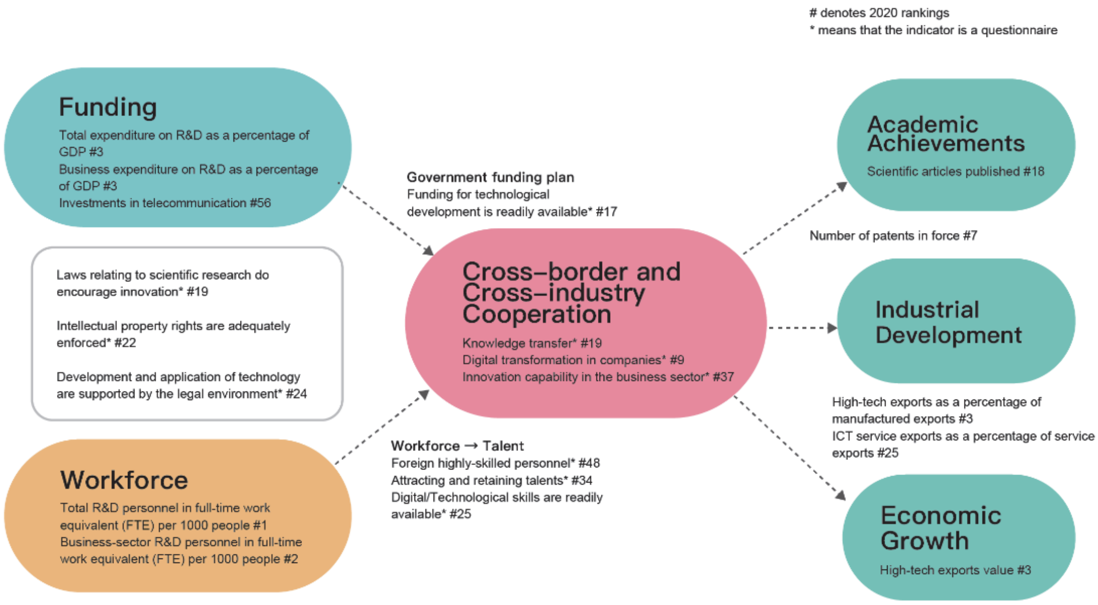

Figure 2-8. The ranking of Taiwan's S&T development value chain in the IMD 2022 World Competitiveness Yearbook (with 2020 as base year)

Data source: IMD World Competitiveness Yearbook 2022, compiled by STPI.

The competitiveness of Taiwan in terms of smart and digital development was also rated in the IMD 2022 World Digital Competitiveness Ranking, which assesses the capacity of an economy to adopt and explore digital technologies and in turn enable and prepare the economy to exploit social and economic transformation. Taiwan ranked 11th out of 63 major economies in the latest World Digital Competitiveness Ranking, which rates three main factors (see Table 2-8) to assess the capacity and readiness of each country to adopt, explore, and exploit digital transformation. Taiwan ranked 18th, 6th, and 8th in the Knowledge, Technology, and Future Readiness factors, respectively. Each factor is further divided into 9 sub-factors and 54 criteria. The report also revealed that Taiwan ranked top three in the world in eight criteria, which were identified as the nation's overall strengths. The top three criteria were Total R&D Personnel Per Capita in the Knowledge factor; and Mobile Broadband Subscribers and IT & Media Stock Market Capitalization in the Technology factor. Taiwan ranked second in Use of Big Data and Analytics under the Future Readiness category. The nation ranked third in Higher Education Achievement and Total Expenditure on R&D under the Knowledge category, in High-Tech Exports under the Technology category, and also in Agility of Companies under the Future

Readiness category. These rankings show that Taiwan has been committed to promoting digital transformation specifically in terms of infrastructure and R&D applications.

Table 2-8 Rankings of Taiwan in sub-factors in the IMD 2022 World Digital Competitiveness Ranking

Criteria	2016	2017	2018	2019	2020	2021	2022	Changes in Ranking from 2021 to 2022
Overall Performance	16	12	16	13	11	8	11	-3
1. Knowledge	**19**	**16**	**19**	**18**	**18**	**16**	**18**	**-2**
(1) Talent	19	18	25	21	18	17	21	-4
(2) Training and Education	23	28	25	20	21	12	11	+1
(3) Scientific Concentration	19	17	13	15	18	19	21	-2
2. Technology	**8**	**7**	**11**	**9**	**5**	**2**	**6**	**-4**
(1) Regulatory Framework	25	24	21	23	16	16	14	+2
(2) Capital	6	8	13	12	8	2	9	-7
(3) Technological Framework	6	4	10	4	4	4	4	-
3. Future Readiness	**22**	**16**	**22**	**12**	**8**	**7**	**8**	**-1**
(1) Adaptive Attitude	19	19	28	14	14	13	13	-
(2) Business Agility	24	6	13	3	1	2	5	-3
(3) IT Integration	24	22	23	24	17	15	13	+2

Data source: IMD World Digital Competitiveness Ranking 2022, organized by STPI.

2.3 Implementation and Results of Major S&T Policies

2.3.1 Major Government Policies and Programs

This chapter reviews major policies and programs of the Executive Yuan, including DIGI+: Digital Nation and Innovative Economic Development Program (2017–2025) and the Forward-Looking Infrastructure Development Program. The implementation focus for each program is described in chronological order, serving as a basis for the strategic planning of this White Paper on Science and Technology (2023–2026).

(1) DIGI+: Digital Nation and Innovative Economic Development Program

(2017–2025) — Smart Nation Program (2021–2025)

In November 2016, the Executive Yuan presented the DIGI+: Digital Nation and Innovative Economic Development Program (2017–2025), set to span a period of four years. With the concerted efforts of various parties, Taiwan has been called one of the world's top four "super innovators" together with Germany, the United States, and Switzerland for two consecutive years, and was also ranked 11th in IMD's 2020 World Digital Competitiveness Ranking. These achievements have laid a digital foundation for Taiwan to support 5+2 industrial innovations and become a smart nation. Presently, Phase 1 (2017–2020) of the DIGI+ program has been completed.

In response to the vision of developing Taiwan into a smart nation, Phase 2 of the DIGI+ program was renamed the Smart Nation Program (2021–2025). The scope of Smart Taiwan included information security, Beyond 5G (B5G), angstrom generation semiconductors, cloud era industry transformation, advanced network infrastructure, and other advanced technologies to promote the overall digital transformation of the nation, society, and industries, strengthen digital competitiveness, and unlock development opportunities for post-pandemic Taiwan. Drawing on the foundation of existing innovations, Smart Taiwan envisions transforming Taiwan into an innovative, inclusive, and sustainable smart nation, where 5+2 industrial innovations are supported to facilitate the development of the Six Core Strategic Industries. The program will integrate and focus on four pillars: Digitization, Innovation, Governance, and Inclusion, with plans to achieve the following targets by 2025:

A. A digital economy of NT$6.5 trillion, growing to 29.9% of the GDP, with an increase in the economic output of digital services (soft) to NT$2.9 trillion.

B. An actively networked society in which the penetration rate for digital lifestyle services reaches 80% and 60% of individuals are digitally competitive.

C. A superior broadband environment wherein broadband internet connections of 2 gigabits per second will be rolled out (to cover 90 percent of users) and 5G networks will cover 85% of non-rural populations.

(2) Forward-Looking Infrastructure Development Program

Looking forward to the development needs of Taiwan in the future, the Executive Yuan approved the implementation of the Forward-Looking Infrastructure Development Program, which is set to be carried out from September 2017–August 2025 to keep pace with the latest industrial, technological and lifestyle trends at home and abroad. With the vision of building a foundation that ensures ecological and regional balance to support national and industrial development over the next 30 years, the program gives priority to urban and rural projects that facilitate regional balance and joint governance, and also to key infrastructures in areas where growth momentum was previously inadequate, in order to accelerate the nation's economic transformation, balanced development, and regional integration. Speedy allocation of budgets to the following eight categories is necessitated to achieve the program objectives: railway infrastructure to provide safe and fast transportation; water environment infrastructure to build resilience against climate change; green energy infrastructure to foster environmental sustainability; digital infrastructure to create a smart and connected nation; urban and rural infrastructure to balance regional development; friendly child care infrastructure to reverse declining birth rate trends; food safety infrastructure; and human resources infrastructure to nurture talent and boost employment.

In the first four years of implementation (September 2017–August 2021), priority based on an active inventory of local infrastructure demands was given to urban and rural projects that facilitate joint regional governance, and also to key infrastructures in underdeveloped areas, thereby promoting regional development as a whole and regional balance, which will substantially improve infrastructures for transportation, environmental improvements, digital transformation, renewable energy, education, and social welfare. Over the next four years (September 2021–August 2025), projects implemented in the first four years will be continued if necessary, and priority will be given to major infrastructures that can be completed by 2025. Apart from that, the government will considerably increase funding for projects that support the infrastructure for post-pandemic digital development (e.g., 5G communications, artificial intelligence, and corporate digital transformation), and raise the proportion of funding for projects involving infrastructures for the Six Core Strategic Industries, for industrial revitalization, and for balanced regional development. Moreover, these infrastructure projects are required to adopt the concept of sustainability transformation, green recovery, and ecology check and to take into account the country's sustainable development goals.

(3) Taiwan Science and Technology Roadmap (2019–2023)

According to Article 9 of the Fundamental Science and Technology Act, the government shall present a written statement once every two years describing the visions, strategies, and current status of scientific and technological development. The Taiwan Science and Technology Roadmap (2019–2022) was established upon the consensus reached at the 10th National Science and Technology Conference. In the spirit of continuing legacy and upholding people-centered core values, the Roadmap prepares Taiwan for future challenges by providing an international overview and analysis of material issues that pertain to Taiwan and presenting response strategies and S&T plans in five main dimensions: Health and social security, industry and economy, energy resources and environment, education and culture, and infrastructure. To realize the Roadmap vision, S&T development in Taiwan will follow the four guiding principles of consolidating basic research, encouraging scientific research applications, tapping into the values of entrepreneurship, and integrating S&T and culture, in order to promote industrial transformation through S&T innovation, boost Taiwan's economic development, fulfill the requirements for social development, demonstrate the economic and social benefits of science and technology, create competitive advantages for Taiwan, sustain Taiwan's position as the world's leading innovator, and build a nation through science and technology.

(4) National Science and Technology Development Plan (2021–2024)

According to Article 10 of the Fundamental Science and Technology Act, the government shall formulate a National Science and Technology Development Plan once every four years reflecting the nation's developmental trends, the needs of society, and the goal of balanced regional development; this Plan shall take into consideration the consensus and conclusions reached at the National Science and Technology Conference and shall serve as a basis for formulating scientific and technological policies and promoting scientific and technological research and development. Accordingly, the Executive Yuan convened the 11th National Science and Technology Conference in December 2020, focusing on the 2030 vision of making Taiwan innovative, inclusive, and sustainable. The conference was aimed to use innovative thinking, incorporate technologies for solving the problems of all industries, preemptively deploy key technological strategies, and integrate the six core strategic industries to strive toward becoming a country that excels in innovation. With inclusiveness at the core, the vision addresses the needs of different generations, populations, and domains, deepens the care for local society, enriches the diversity of local culture, and creates a safe, diverse, and inclusive society. In response to the sustainable development goals (SDGs) of the United Nation, the scientific and technological development strategies for economic growth, social development, and environmental protection are promoted to create a co-existing, prosperous, and sustainable society.

To strengthen balanced regional development, the government aims to upgrade and promote the six core strategic industries based on the "five plus two" industry innovation plan; integrates the advantages of science parks to shape Northern, Central, and Southern Taiwan into characteristic industry clusters; strengthens ties to local demands and the integration of the capacity of industries, academia, and research institutes; and assists science parks in cultivating talented professionals in industrial technology and promoting local employment, thereby generating the critical mass that drives the development of regional economy. In the future, science parks will continue to connect local businesses, bolster the advantages of regional industries, and cooperate closely with local governments to promote the development of regional economy and industries and boost local prosperity.

With a focus on the future needs of Taiwan, different channels, both virtual and physical, were adopted to collect the opinions of various industrial practitioners, summarize the actions that should be taken, and request each industrial representative to reach a consensus on S&T development. Various ministerial departments cooperated to establish key strategies and measures, which encompass the following four goals and response actions: Refine the talent cultivation environment and create advantages for talent recruitment; improve the research and development ecosystem and allocate resources for the development of pioneering technology; co-create economic momentum and build a solid ground for innovation; enhance smart living capacity and realize a secure society. The achievement of these goals can boost the development of talents, scientific research, industries, and the society. Through early deployment, the four needs of Taiwan: the need for industrial talents, the need for scientific research capacity, the need for industrial transformation, and the need for a secure society, can be satisfied, meeting not only the expectations of Taiwanese nationals but also the U.N. sustainable development goals, thereby realizing the 2030 vision of Taiwan—Innovation, Inclusion, and Sustainability.

(5) Program for Promoting Six Core Strategic Industries

The Executive Yuan approved the Program for Promoting Six Core Strategic Industries on May 21, 2021. By building on the existing foundations of the 5+2 industrial innovations through timely deployment of industries, this program aims to take early advantage of global supply chain transformations in the post-pandemic era to position Taiwan as a key power in the world economy. The six core strategic industries are information and digital industries, cybersecurity industry, precision health industry, green and renewable energy industry, national defense and strategic industries, and strategic stockpile industries. The Program is jointly promoted by the

Ministry of Economic Affairs, NSTC (formerly MOST), Ministry of Transportation and Communications, Ministry of Health and Welfare, and the National Development Council to accelerate the upgrading and transformation of industries in Taiwan, and transform this country into a critical force in the future global economy. The strategies for each industry are detailed below:

A. Information and digital industry

To keep abreast of business opportunities derived from ICT and semiconductor industries, Taiwan will be developed into a critical base for next generation information and communications technology to establish Taiwan as a digital hub and contributor of global prosperity and security. To date, the government has incorporated eight actions into the focus of implementation in order to keep pace with the development of information and digital industries: Develop next-generation semiconductor manufacturing technology; cooperate with companies at home and abroad to develop semiconductor devices and materials; develop internationally recognized 5G communication technologies; develop Edge AI computing industry; develop micro LED and next-generation automobile electronic technology and keep abreast of business opportunities relating to smart display and smart vehicles; screen well-performing manufacturers for AIoT solutions; develop transportation, healthcare, and retail hospitality applications by using 5G technology and inter-government agency data transmission platforms; and engage in international cooperation on the development of 5G communication technology for open network applications.

B. Cybersecurity industry

In response to advancements in 5G communication, artificial intelligence, and Internet of Things (IoT) technologies, which will drive digital transformation and the continual increase in demand for smart integration, Taiwan must strengthen its cybersecurity industry to promote the development of the digital economy as a whole, and aim to construct globally trusted cybersecurity systems. To date, the government has incorporated four actions into the focus of implementation in order to keep pace with the development of the cybersecurity industry: Implement scientific projects to conduct research and development on IC design testing, 5G communications, and other cybersecurity technologies as well as AI-assisted detection technology; establish cybersecurity inspection and management mechanisms for 5G networks and software; develop cybersecurity products by establishing a team that comprises cybersecurity companies and emerging industries such as 5G communication technology, IoT, and healthcare; and establish cybersecurity organizations to engage in frontier research on cybersecurity, international cooperation, and talent development.

C. Precision health industry

Precision health takes into account differences in a person's genes, environments, lifestyles, and disease composition and formulates a precise strategy for prediction, prevention, diagnosis, and treatment of the disease. Precision health is broader in scope, encompassing risk assessment, prevention and health promotion before disease onset. Given the global trends in precision health and the current status of development in Taiwan, Taiwan will be established as a benchmark nation in precision health and epidemic control technologies. To date, the government has incorporated five actions into the focus of implementation in order to keep pace with the development of the precision health industry in Taiwan: Build a Biobank and National Health Insurance Research Database; develop precision prevention, diagnosis, treatment and care systems; develop precision epidemic prevention products; expand international biomedical business opportunities; and adopt cybersecurity in precision health.

D. National defense and strategic industries

Space technology is a cutting-edge technology in Taiwan that is characterized by high added value. Its key components are heavily regulated. Therefore, the capacity to develop space technology autonomously and independently is a symbol of national strength. Taiwan has developed complete industrial clusters in such sectors as semiconductors, ICT, and precision machinery, each of which has demonstrated outstanding performance. Furthermore, experiences in the development of Formosat-5 and Formosat-7 can provide a foundation for developing Taiwan's space industry. Therefore, the vision is to position Taiwan as an important supplier in the global aviation, ship-building and space industrial ecosystems.

The government has thus far incorporated 10 actions into the focus of implementation in order to keep pace with the development of the national defense and strategic industries: Build a F-16 Fighter Jet Maintenance Center; assist with the upgrade and transformation of existing suppliers to improve the aviation and ship-building supply chain; develop key/core aviation and ship-building technologies; set up a national defense S&T research center to develop highly skilled personnel; promote the transfer of military-civilian technology and assist in obtaining international certifications; strengthen remote sensing satellite bus/payload and ground equipment technology; produce B5G communication satellites and strengthen ground equipment technology; build space part testing platform and conduct pilot test and verification on Made-in-Taiwan components; promote Taiwan's national space brand; adopt cybersecurity in the national defense and strategic industries.

E. Green and renewable energy industry

Greenhouse gas (GHG) emissions are a leading cause of climate change. Countries worldwide have all pledged to reduce GHG emissions as part of their environmental policy and invested in the development and promotion of renewable energy such as wind and solar energy. The present marks a critical moment for transitioning to clean energy. To achieve the target of 20% renewable energy generation by 2025 and boost the development of emerging renewable energy industries, the government has launched a Promotion Program for Green Energy Technology Industries under the 5+2 industrial innovations framework to meet the green demands of Taiwan by attracting large investments from Taiwan and foreign countries. On this foundation, Taiwan will continue to promote green electricity and renewable energy industries to ensure successful energy transition by 2025 and meet green electricity demands in the business sector. In addition, by forming a national team for offshore wind power industry, the country will attempt to gain a crucial role in the Asia-Pacific wind power supply chain, thereby transforming into a green energy hub in Asia Pacific. The government has incorporated seven actions into the focus of implementation in order to keep pace with the development of the green and renewable energy industries: Set up industrial parks and R&D bases; develop Maritime Technology Innovation Center's capacity to construct underwater foundations; develop a sound green electricity system and national financing guarantee mechanism; form a national team that takes charge of offshore wind power systems; form a national team that takes charge of offshore wind underwater foundations and maritime projects; join forces with international suppliers to gain access into Asia-Pacific wind power industries; and adopt cybersecurity in green electricity and renewable energy industries.

F. Strategic stockpile industries

The COVID-19 pandemic in 2020 caused global supply chain disruptions, which led to a surge in demand for medical and daily supplies. However, many countries had faced shortages of suppliers because trade globalization had weakened supply chain resilience. Given the risks associated with supply chain disruptions and supply shortage, countries will pay more attention to the stability of key suppliers, strengthen the nation's strategic stockpiles and production capacity, reinforce international cooperation, and build a sustainable key supply chain that is more resilient to external impacts. The government has incorporated eight actions into the focus of implementation in order to keep pace with the development of the strategic stockpile industries: diversify energy importation and increase secure stockpile of natural gas; guide pharmaceutical companies to develop pharmaceutical products and obtain drug licenses, and guide medical device suppliers to obtain certification to establish global presence; strengthen the provision of critical supplies for civilians; ensure self-sufficiency in the supply and demand of sand and gravel; diversify the distribution of sand and gravel sources; and adopt cybersecurity measures for strategic stockpile industries.

(6) Asia Silicon Valley Development Plan 2.0

The National Development Council (NDC) launched the Asia Silicon Valley Development (ASVD) Plan in September 2016 in collaboration with the Ministry of Economic Affairs, NSTC (formerly MOST), and Ministry of Transportation and Communications. The Plan has two primary goals: firstly, promoting IoT development, and secondly, enhancing the ecosystem of innovation and entrepreneurship in Taiwan, both of which have come to fruition, as evidenced by the output value of the IoT sector in Taiwan, which has exceeded a trillion NTD, making the IoT sector a trillion-dollar industry. The Plan has also assisted startups in obtaining funds for development and participation in international exhibitions, and cemented a solid foundation for the digital transformation of industries in Taiwan.

With the rapid development of AI and 5G technologies in recent years, the application of IoT has been widely adopted, spurring the rise of various innovative services that invigorated startup ecosystems in Taiwan. Hence, the growth and exit of startup businesses must be accelerated. Building on the foundation of ASVD Plan 1.0, the NDC and various ministerial departments, with the approval of the Executive Yuan in August 2021, coordinated in the planning of ASVD Plan 2.0. With the vision of making Taiwan a key digital innovator in Asia, Plan 2.0 is focused on two main pillars: Accelerating industrial evolution with AIoT and driving the future of industries with innovation and entrepreneurship, and three main strategies: expanding the application of AIoT technologies, improving the environment in Taiwan to drive entrepreneurship, and consolidating system output capacity. ASVD Plan 2.0 is implemented from 2021 to 2024 and is expected to yield the following benefits: Cultivate 3 world-class system integrators in Taiwan; increase Taiwan's IoT global market share to 5% by 2025; export

20 AIoT solutions; facilitate 40 successful startup exits; and assist 200 startups to succeed.

(7) Taiwan's Pathway to Net-Zero Emissions by 2050

In March 2022, the Taiwanese government published a general description of Taiwan's Pathway to Net-Zero Emissions by 2050 and the strategies involved, outlining the trajectories and actions for net-zero transition by 2050. Aimed at promoting technology R&D and innovation in key areas, guiding the green transition of industries, and driving a new wave of economic growth, this blueprint is expected to promote green financing and increase investment at various key milestones in order to ensure a reasonable transition period.

Taiwan's 2050 net-zero emissions pathway is based on four areas of transition: energy, industrial, lifestyle, and social transition, and two areas of governance: technology R&D and climate legislation. Supplemented by 12 Key Strategies, the pathway outlines action plans with respect to energy, industrial, lifestyle, and social transition policies for achieving net-zero transition in key areas in which growth is anticipated.

By establishing strategies and a governance foundation for the vision of ensuring competitive, sustainable, resilient, and secure transition to promote economic growth, drive private investment, generate green jobs, achieve energy autonomy, and enhance social well-being, the "2050 Net-Zero Transition" affects not only competitiveness but also environmental sustainability; therefore, a foundation for long-term growth and stability must be established to make Taiwan a better place for future generations.

2.3.2 Research Achievements

(1) NSTC Fundings for Research Projects

To raise the intensity of S&T research and development in Taiwan, the NSTC (formerly MOST) encourages research in universities and research organizations by providing research fundings and grants. Each year, NSTC allocates a certain amount of funding to research projects that involve natural science, engineering and applied science, life science, humanities and social science, and science education. In 2021, the NSTC allocated funding to 1,637 research projects undertaken by the Department of Natural Science; 3,737 projects by the Department of Engineering and Applied Science; 2,534 projects by the Department of Life Science; 3,758 projects by the Department of Humanities and Social Science; and 204 projects by other departments. Table 2-9 summarizes the status of NSTC funding for research projects.

Table 2-9 Statistics of the funding status of NSTC-funded projects (by department)

Unit: NT$ Million

Department	2018		2019		2020		2021	
	No. of Projects	Amount	No. of Projects	Amount	No. of Projects	Amount	No. of Projects	Amount
Natural Science	1,899	5,425.38	1,774	5,440.29	1,605	5,341.23	1,637	5,681.40
Engineering and Applied Science	4,038	8,144.70	3,729	7,827.97	3,876	7,851.29	3,737	7,484.56
Life Science	2,630	6,976.67	2,574	7,432.24	2,610	7,528.09	2,534	7,200.81
Humanities and Social Science	3,669	4,233.83	3,736	4,370.37	3,641	4,446.11	3,758	4,433.99
Others	351	4,705.70	335	4,676.97	212	4,469.48	204	3,248.67
Total	**12,587**	**29,486.27**	**12,148**	**29,747.84**	**11,944**	**29,636.19**	**11,870**	**28,049.42**

Data source: NSTC Statistics Database, organized by STPI.

Note: The Department of Science Education was consolidated into the Department of Humanities and Social Science in 2018.

(2) Academic Articles and Patent Performance

In this section, we analyze and compare indicators of competitiveness in relation to academic articles published by Taiwanese authors and patents approved by the United States Patent and Trademark Office (USPTO). The purpose of this section is to analyze the development trends and global competitiveness of Taiwan in various subject areas and technological areas, thereby identifying Taiwan’s strengths and potential.

Regarding trends in the publication of journal articles, the United States, China, and United Kingdom were the top three countries that published the highest number of articles during 2017–2021. Taiwan ranked 21st in the world and 7th in Asia. Table 2-10 shows the rankings in terms of the number of Taiwanese-authored articles that were indexed by Science Citation Index (SCI) and Engineering Index (EI) in recent years.

Table 2-10 Rankings in terms of the number of Taiwanese-authored articles published in recent years

Year	2017		2018		2019		2020		2021	
Articles	No. of Articles	Ranking	No. of Articles	Ranking	No. of Articles	Ranking	No. of Articles	Ranking	No. of Articles	Ranking
SCI-Indexed Articles	26,062	21	26,093	22	29,178	21	32,821	21	37,690	22
EI-Indexed Articles	20,049	19	20,317	19	19,925	20	20,441	20	21,113	20

Data source: InCites, Clarivate Analytics (2022) and Compendex (2022), organized by STPI.

Based on the 22 categories used in the Essential Science Indicators (ESI), the number of Taiwanese-authored articles published between 2017 and 2021 reveals that published articles by Taiwanese authors were mostly related to clinical medicine, engineering, chemistry, material science, and physics. For each category, an average of more than 2,000 articles per year have been published in recent years. In other words, Taiwanese authors tend to publish articles on these subject areas. The number of published articles on environment and ecology, social science, computer science, mathematics, biology, and biochemistry has been increasing annually, while the number of articles on space science, neuroscience, and behavioral science has been stable.

Regarding article citation, the number of times SCI-indexed articles published by Taiwanese authors have been cited over a period of five years and the average number of citations per article were calculated (see Table 2-11). The results show that the number of citations has been increasing in recent years due to a slight increase in the publication of Taiwanese-authored papers. Between 2014 and 2018, each SCI-indexed article published by Taiwanese authors was cited 6.44 times on average, which increased to 7.98 times in 2017–2021. Taiwan ranked 26th in the world with respect to the total number of citations.

Table 2-11 Citation of SCI-indexed articles published by Taiwanese authors in recent years

Period	2014–2018		2015–2019		2016–2020		2017–2021	
Journal Articles	No. of Articles	Ranking	No. of Articles	Ranking	No. of Articles	Ranking	No. of Articles	Ranking
SCI-indexed Articles Cited	866,156	22	925,901	24	1,028,189	26	1,293,531	26
Average Citation per SCI-indexed Article	6.44	-	6.83	-	7.28	-	7.98	-

Data source: InCites, Clarivate Analytics (2022), organized by STPI.

Competitiveness analysis for each subject category was performed by assessing the percentage of articles relative to the world and relative impact in each category, with world average as the baseline for comparison. Percentage of articles relative to the world represents the percentage of articles in a given category relative to the total number of articles in that category in the world. The greater the percentage, the higher the number of articles in that category in the world. The Category Normalized Citation Impact (CNCI) indicator was used as the relative impact indicator; it is calculated by dividing the actual count of citing items by the expected citation rate for documents with the same document type, year of publication and subject area. A CNCI value above one represents performance above world average.

An overview of the competitiveness performance of Taiwanese-authored articles in each subject category (Figure 2-9) shows that Taiwan has strengths in the areas of computer science, economics and business, and space science according to the percentage of articles relative to the world. The relative impact of Taiwanese-authored articles performed favorable in the categories of space science, physics, mathematics, botany and zoology, and clinical medicine. In particular, space science, exhibited significant advantage in terms of impact factor and percentage relative to world, implying that Taiwan is most competitive in this category. Chemistry, environment and ecology, material science, and engineering are four categories considered to be steadily developing in terms of percentage relative to world or relative impact. Although botany and zoology had low percentage relative to the world, its relative impact was high, suggesting articles in this category are characterized by low quantity and high quality.

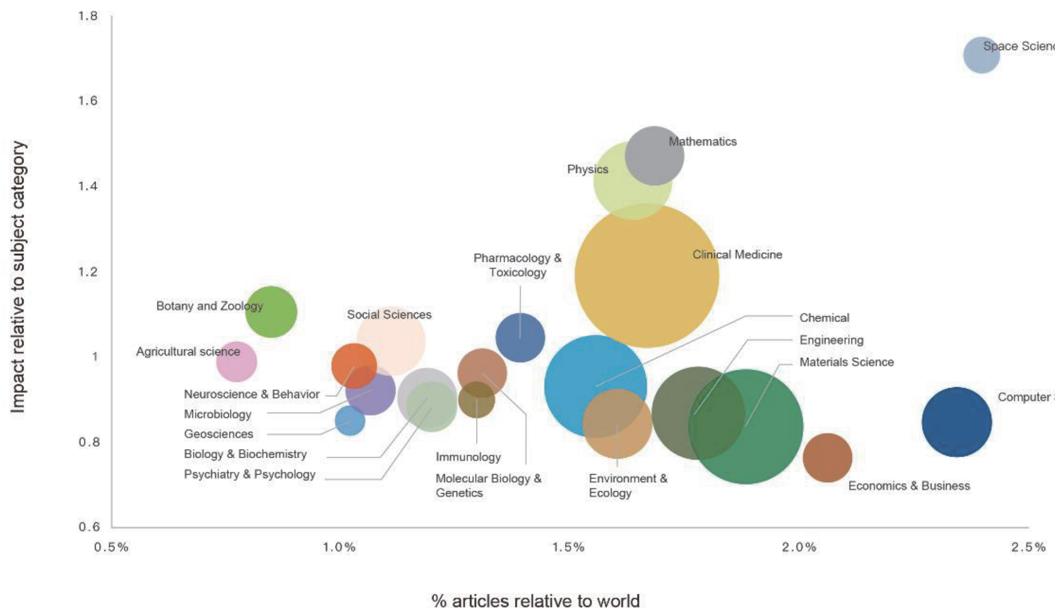

Figure 2-9 Competitiveness of Taiwan in each subject category

Data source: InCites, Clarivate Analytics (2022; scope of analysis: 2017–2021); organized by NSTC and STPI.

Regarding international patent publication, Taiwan ranked 5th in the world in terms of number of USPTO-approved patents but dropped to 6th in 2017, which continued through to 2021. The number of approved patients dropped slightly from 12,535 patents in 2017 to 11,857 patents in 2019; however, it began increasing in 2020, reaching 12,648 patents in 2021. Noticeably, the number of approved patents increased to 13,390 in 2020 (Table 2-12), which indicates that Taiwan still actively applied for intellectual property rights for its industrial S&T development even during the outbreak and ongoing impact of COVID-19. As one of the countries in the world holding the highest number of patents, Taiwan remains competitive in global innovation, but it still needs to actively encourage patent application and produce high-quality patents in order to maintain the country's competitive edge in S&T development.

Table 2-12 Number of USPTO-approved patents in each country and rankings

Country	2017		2018		2019		2020		2021	
	No. of Patents	Rank	No. of Patents	Rank	No. of Patents	Rank	No. of Patents	Rank	No. of Patents	Rank
US	167,367	1	161,965	1	177,050	1	188,344	1	170,059	1
Japan	51,741	2	50,012	2	53,172	2	55,899	2	48,909	2
South Korea	22,689	3	22,054	3	22,427	3	24,218	4	29,469	3
China	14,154	5	16,315	5	20,836	4	26,176	3	23,128	4
Germany	17,994	4	17,434	4	18,758	5	19,799	5	17,971	5
Taiwan	**12,535**	**6**	**11,424**	**6**	**11,857**	**6**	**13,390**	**6**	**12,648**	**6**
UK	7,636	7	7,549	7	8,494	7	8,834	7	8,215	7
Canada	7,539	8	7,225	8	7,790	8	8,179	8	7,669	8
France	7,365	9	6,991	9	7,532	9	7,981	9	6,960	9
India	4,207	11	4,248	10	5,075	10	5,888	10	6,114	10

Data source: USPTO, Performance and Accountability Report, 2021; organized by NSTC and STPI and reviewed in 2022.

The performance of Taiwan in the field of technology was analyzed according to the 5 main technology fields and 35 subfields as defined by the World Intellectual Property Organization (WIPO). Two indicators, affinity index and activity index in relation to a technology field, were used to analyze the affinity and activity of each category of patent in the technology fields of Taiwan. The results are shown in Figures 2-10 and 2-11. Affinity index for scientific field refers to the ratio of citation of Taiwan's patents in scientific literature (Non-Patent Literature, NPL) relative to the ratio of the world in the same field (NPL). An affinity index greater than one indicates that the level of affinity of Taiwan toward science in a certain technology field is above world average. According to statistics, technology fields in Taiwan that have a high affinity to science include audio-visual technology, basic communication processes, microstructure and nanotechnology, optics, and semiconductors (Figure 2-10). In other words, Taiwan has a high affinity to the development and scientific research of these technology fields. Activity index in a technology field refers to the ratio of Taiwan's patents in a technology field relative to the ratio of the world in the same field. An activity index greater than one indicates that the activity of Taiwan in a certain technology field is above world average. Figure 2-11 shows that Taiwan is more active than the world average in the fields of audio-visual technology, basic communication processes, computer technology, microstructure and nanotechnology, optics, and semiconductors. In other words, Taiwan holds advantages in these technology fields and performs better than its world counterparts.

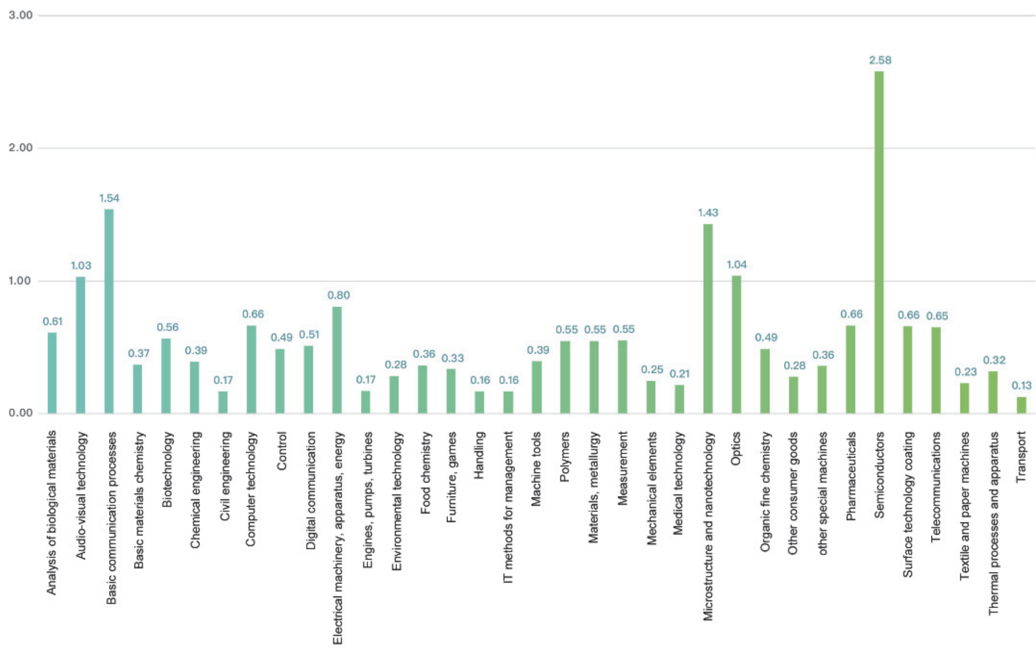

Figure 2-10 Scientific affinity of Taiwan's patents in various technology fields

Data source: Organized and compiled by NSTC and STPI.

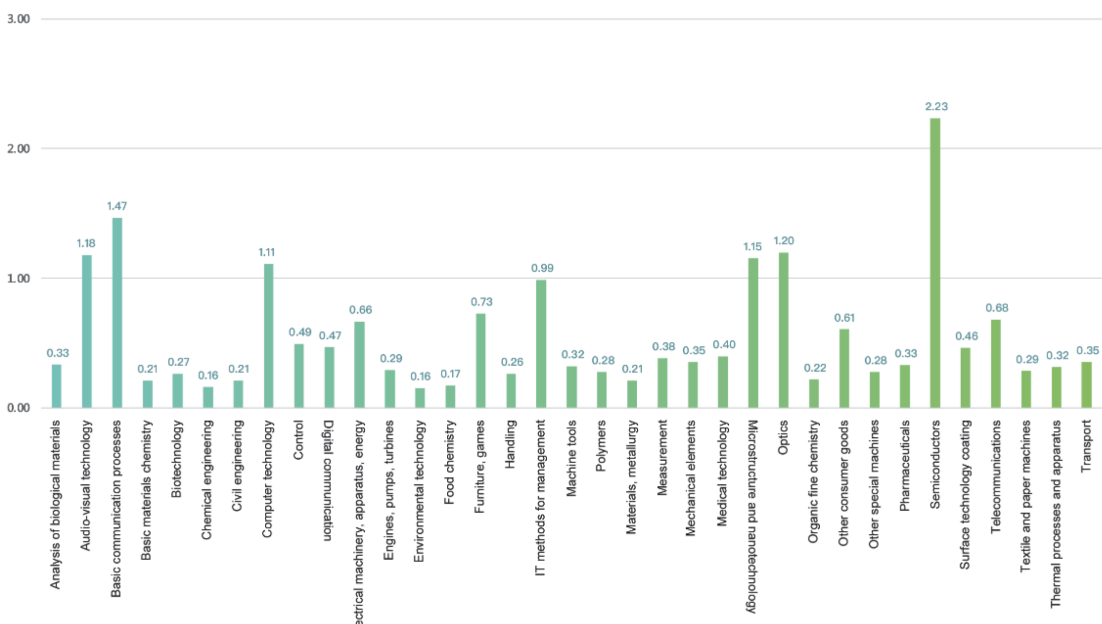

Figure 2-11 Activity index of Taiwan in each technology field

Data source: Organized and compiled by NSTC and STPI.

A general analysis of Taiwan's competitiveness in academic fields and its performance in technology fields reveals that Taiwan possesses competitive edge in scientific research and industry S&T capacity. The country also shows development potential in multiple fields. In face of challenges from the COVID-19 pandemic, geopolitical conflicts, and global climate change and of global advances in S&T development as well as groundbreaking innovations, Taiwan should concentrate its resources on niche technology fields that show potential and strengths and meet the needs of the future. By developing its specialty fields in science and technology, Taiwan can gain a point of entry into new, emerging technology fields, and create a friendly, inclusive scientific research environment that helps to foster interdisciplinary and talented scientific researchers. Through interdisciplinary collaboration across industrial, academic, and research sectors and cooperation on the value of global democracy, the scientific research foundation of Taiwan and the S&T capacity of industries in Taiwan can be further cultivated. Moreover, scientific research seeds that are globally influential and contribute to the democratic value and well-beings of people in society can be converted into strategic applications that help Taiwan to generate a global impact on S&T, thereby gaining a key role in international communities and the trust of its alliances.

2.3.3 The Current Status of Science Parks in Taiwan

Science parks have a vital role to play in the development of high-tech industries and S&T talents. These parks can promote industry upgrade, regional balance, benchmark demonstration, and technology diffusion. Science parks have been established in appropriate areas of Northern, Central, and Southern Taiwan to support the country's policy plans for industries. Science parks in Taiwan are geographically clustered into three areas of Taiwan: Hsinchu, Central, and Southern Taiwan (see Table 2-13). Science parks in the Hsinchu (HSP) cluster include Hsinchu, Jhunan, Tongluo, Longtan, Yilan, and Hsinchu Biomedical Parks. In the Central Taiwan cluster, there is the Central Taiwan Science Park (CTSP), the main park which branched into five more science parks, namely, Taichung Park, Huwei Park, Houli Park, Erlin Park, and Chung

Hsing Park. In the Southern Taiwan cluster, the Southern Taiwan Science Park (STSP) is the main park, which branched into Tainan, Kaohsiung, and Ciaotou Science Parks. At the beginning of 2022, the government has set to establish Chiayi and Pingtung Science Parks to build an S&T corridor in Southern Taiwan. As at the end of August 2022, 615, 235, and 264 companies have set up base in HSP, CTSP, and STSP, respectively, and there are 168,215 people, 53,206 people, and 90,971 people working in each park, respectively. The parks have established their respective development goals and focuses. Their reported total annual revenue nearly doubled during 2012–2021 (Figure 2-12).

Table 2-13 Background information of HSP, CTSP, and STSP

	HSP	CTSP	STSP
Branches	Hsinchu, Jhunan, Tongluo, Longtan, Hsinchu Biomedical, and Yilan Parks	Taichung Park, Huwei Park, Houli Park, Erlin Park, and Chung Hsing Park	Tainan, Kaohsiung, and Ciaotou
Area	1,376 ha	1,485 ha	1,873 ha
Industry Cluster	IC, computers and peripherals, communication, optoelectronics, precision machinery, biotechnology	Optoelectronics, precision machinery	Semiconductors, biotechnology and medical devices, precision machinery, optoelectronic green energy
Number of Companies	615	235	264
Number of Employees	168,215	53,206	90,971
Development Goals and Focus	Implement policies that facilitate succession and innovation, and formulate two main strategies: (1) Optimize investment environment for industrial sustainability: Focus on investments for the sustainable development of industries in the science park, including Phase 2 Expansion of HSP in Baoshan Project, Construction of a 3rd Biotechnology Building in the Biomedical Park; and Functional Enhancement of Wastewater Treatment Facility in Tongluo Park. (2) Improve innovative	Become innovation-driven, protective of the environment, local-friendly, and internationally oriented by achieving four main development goals: (1) Encouraging high-tech companies to make a breakthrough; (2) Construct a positive environment that facilitates sustainability and attracts quality investments; (3) Develop an effective industry cluster by combining	Development focuses: (1) Create science park strengths and strengthen industry clusters: by closing the gap between semiconductor, medical device, and aerospace supply chains, attracting business investments, and boosting the competitiveness of industrial clusters at the STSP. (2) Improve services for sustainability: by ensuring land use and water/electricity supply, adopting long/short-term power supply strategies, and attracting the presence of high-tech industries,

	HSP	CTSP	STSP
	services to inspire creativity: Promote the integration of corporate venture capital (CVC) in the science park and entrepreneurial teams to attract new investments, which will promote international cooperation, digital technology integration, and workforce demand platform, thereby creating sites in the park for testing smart applications and improving the innovation capacity of industries in the science park.	regional resources and surrounding industries to strengthen the cluster effect of CTSP-featured industries; and (4) Build a base that drives innovation and entrepreneurship.	which will create economic value and job opportunities. (3) Create a friendly environment that embraces the value of production, daily living activities, ecology, and life: By promoting and implementing environmental policies on water/electricity conservation, green electricity, and tree planing to reduce the ecological/environmental impact of production and development activities.
Note (Expansion Projects)	In 2022, the Executive Yuan has approved the Phase 2 Expansion of HSP in Baoshan Project, Construction of a 3rd Biotechnology Building in the Biomedical Park, and the Construction of Three Software Buildings at X Base in HSP.	In January 2022, the Executive Yuan has approved the CTSP Taichung Park Phase-2 Expansion Preparation Project.	(1) In April 2020, the Executive Yuan approved the STSP Tainan Park Expansion Project (2) In January 2022, the Executive Yuan approved the Pingtung and Chiayi Science Parks Preparation Project for the Construction of a Southern Taiwan S&T Corridor

Data source: Websites of HSP (http://www.sipa.gov.tw/), CTSP (http://www.ctsp.gov.tw), and STSP (https://www.stsp.gov.tw); and S&T statistics published by NSTC (August 2022); organized by STPI.

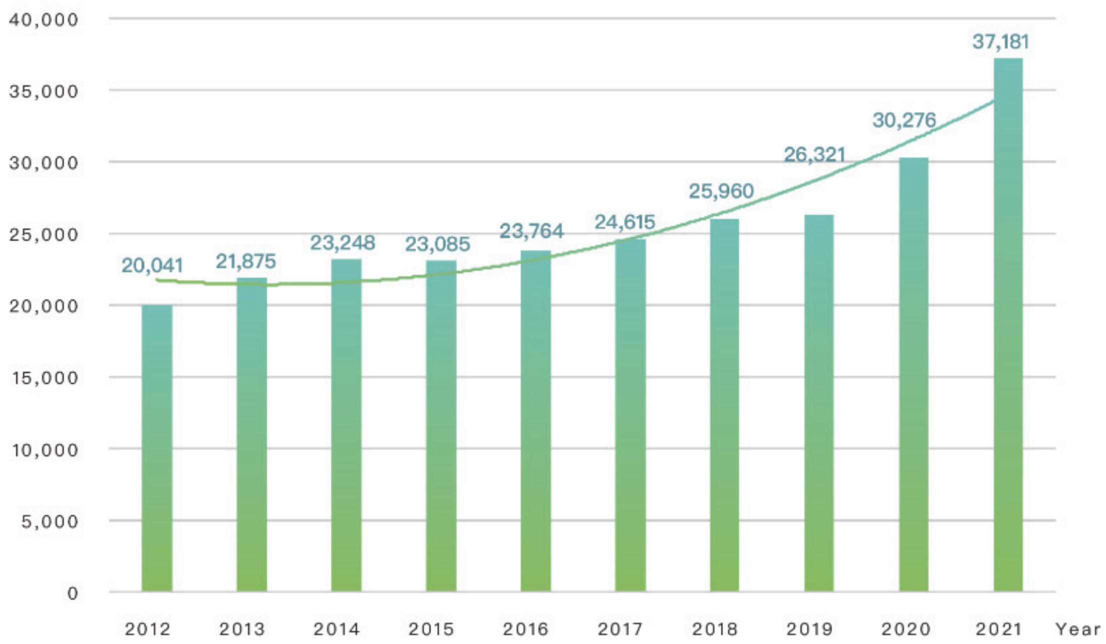

Figure 2-12 Total revenue of HSP, CTSP, and STSP in the past ten years (Unit: NT$100 million)

Data source: S&T statistics published by NSTC (August 2022); organized by STPI.

To demonstrate its determination, the Taiwan government launched programs to accelerate and attract investments in Taiwan through public and private partnerships. At the 12^{th} meeting on the Action Plan for Accelerated Investment Programs in Taiwan held on July 3, 2018, the government emphasized the need to develop the new towns in Kaohsiung City into a science park and the need to expand STSP. Accordingly, the "KSP's (Ciaotou) Phase II Preparation and Development Project" and the "STSP Expansion of TSP Project" were respectively ratified by the Executive Yuan on December 6, 2019 and April 24, 2020. To create more synergy for existing industry clusters in STSP and to promote regional development, on January 3, 2022, preparation of Pingtung Science Park and Chiayi Science Park was ratified by the Executive Yuan to complete the building of an S&T corridor in Southern Taiwan and strengthen regional economic resilience.

For HSP, the government also tapped into the existing advantages of the IC industry in the science park by (1) promoting the expansion of HSP in Baoshan area, which will including upgrading and revitalizing facilities in HSP to ensure the dynamic of industrial development, then (2) constructing a third biotechnology building in the Biomedical Park to strengthen the niche of biotechnology industry clusters, and (3) developing three software buildings at the X Base in HSP to attract interdisciplinary talents in software and hardware integration. The objectives of these actions are to lay a foundation for the software and hardware integration industry in hopes of maintaining the competitiveness of Taiwan's high-tech industries and inadvertently promoting industry upgrade to create legendary industries in Taiwan.

2.3.4 International Cooperation

In 2020, the NSTC (formerly MOST) signed 118 cooperation agreements or memorandum of understanding with 41 countries and 3 international organizations to engage in bilateral or multilateral international cooperation. In that year, the Council has entered into cooperation agreement and memorandum of understanding with five international organizations: Institut National du Cancer (INCa), Economic and Social Research Council (ESRC), Ministry of Education, Culture, Sciences and Sports of Mongolia (MECSS), Australian Nuclear Science and Technology Organization (ANSTO), and American Institute in Taiwan (AIT), all in an effort to accelerate the international cooperation and ties of Taiwan.

In 2021, international exchange fundings were mostly approved for international seminars held in Taiwan (279 applications approved), attendance at international conferences by Taiwanese graduate students (154 applications approved), and bilateral agreements for collaborative research projects (117 applications approved). Table 2-14 presents a statistics of funding applications for international cooperation during 2018–2021.

Table 2-14 Statistics on international exchange funding applications submitted and approved during 2018–2021

Funding	2018		2019		2020		2021	
	No. of Applications Submitted	No. of Applications Approved	No. of Applications Submitted	No. of Applications Approved	No. of Applications Submitted	No. of Applications Approved	No. of Applications Submitted	No. of Applications Approved
Doctoral studies abroad	126	104	123	99	127	104	85	70
Post-doctoral studies abroad	164	52	126	43	115	34	76	34
Attendance at international conferences by graduate students	4,851	2,466	4,427	2,619	1,144	688	209	154

Funding	2018		2019		2020		2021	
	No. of Applications Submitted	No. of Applications Approved	No. of Applications Submitted	No. of Applications Approved	No. of Applications Submitted	No. of Applications Approved	No. of Applications Submitted	No. of Applications Approved
International seminars held in Taiwan	430	318	434	317	342	278	354	279
Attendance at international conferences by domestic experts	2,221	970	1,970	898	501	240	85	51
Participation by delegations in international academic organization conferences	51	42	44	36	5	5	1	1
Short-term overseas research for S&T personnel	284	165	268	181	220	194	108	99
Invited visits by foreign S&T personnel	814	532	739	559	246	177	37	23
International training and education activities*	33	14	19	4	7	4	-	-
Bilateral agreements on collaborative research projects**	444	123	291	110	369	113	367	117

Data source: S&T statistics published by NSTC (August 2022); organized by STPI.

Note: *International training and education activities: Calls for submission were suspended in 2021 due to COVID-19 and will resume when the global pandemic eases and Taiwan opens up its border. Whether submissions for 2022 will be called for are pending assessment. **Data only includes new projects approved in that year (not including multi-year projects that were pre-approved).

In summary, international S&T cooperation must be focused on building opportunities and bridges for international cooperation in key areas to enhance interaction and exchanges with researchers from various countries. For instance, Taiwan and other countries could jointly organize topic-specific seminars and seek bilateral international cooperation research projects, in order to fortify international ties, thereby enhancing the country's R&D capability and promoting talent development, so as to keep pace with the research and development of emerging technologies for frontier industries in Taiwan and generate a new momentum for innovation and entrepreneurship.

Chapter 3 General Goals

Ten general goals have been set for this White Paper on Science and Technology. Details are described below.

Goal 1: Promote gender equality, inclusive technology, and Appropriate Technology to improve the well-being of various groups and achieve mutual prosperity in society

To meet the needs of different social groups, the government aims to adopt gender perspectives and various group participatory designs in planning S&T development; use appropriate technologies to help reduce discrimination between genders and among social groups; promote gender mainstreaming; and create a fair, just, and gender-friendly society. This goal will be achieved by taking the following actions:

1-1. Create a gender-equal environment: Build a scientific research environment in which gender equality is advocated, reinforce the adoption of gender perspectives in technology development, develop an environment and space with gender perspectives, and promote the development of scientific research through gendered innovation approaches. Create female-friendly careers by providing suitable child care and nurseries, increase employment opportunities and conditions for women by providing flexible job vacancies with platform economy where labor rights are protected, and offer online courses for flexible learning and certification, in order to strengthen female empowerment and independence, and achieve fair allocation of economic resources.

1-2. Encourage female to participate in scientific research activities: In order to support female engagement in STEM (science, technology, engineering, math) learning and research, foster female professionals in S&T policy planning, include STEM in early childhood education and basic education, organize STEM social group activities that welcome female participation, and keep track of the effectiveness of such activities for an extended period of time. In the meantime, encourage enterprises that specialize in STEM to hire women and promote women to management (preferably, the number of female managers should be increased by 10% in four years and female managers should account for one third of all managers within eight years), establish a female role model in scientific research to strengthen women's sense of belonging in this field, and effectively increase the number of women in the STEM field. Hopefully the gender gap between STEM-specializing enterprises and scientific research personnel will be shortened by more than 5%, thus boosting Taiwan's technological development and competitiveness.

1-3. National health and care: To address the long-term care needs of a rapidly aging society while promote gender equality and healthcare, adopt affordable and people-centered assistive technology (e.g. caregiving robot indoor/outdoor with smart position setting, wearable and non-wearable smart mobility devices), so as to reduce occupational injury of personal care attendant (there are about 90,000 care providers in Taiwan)[2] extend their service time, and improve quality of care provided to elderly people with disabilities. In order to improve the health of people, develop an active reminder and incentive mechanism based on individual health and physical activities to increase their average life expectancy by 0.5 years per year.

1-4. Cultural equity: Open access to the public sector's collection of digital archive data, and encourage people of different social background and civic groups to utilize user-friendly citizen curation software so as to achieve a data usage rate that is projected to increase by 10% each year. Meanwhile, increase the accessibility of public digital cultural contents; and build a digital curation platform and digital culture portal website to showcase life experience and culture of different social groups.

1-5. Improve rural transportation: Introduce a ride-hailing platform with device positioning function, friendly for rural and elderly residents' use, and make it more flexible, through regulatory amendments by the Ministry of Transportation and Communications, and combines innovative cooperative organizations to establish a point-to-point comprehensive pick-up service that

[2]Ministry of Health and Welfare (2020), Long-term Care 2.0: Current Progress and Review Report at the 10th meeting of 7th session of 10th Social Welfare and Environmental Hygiene Committee of the Legislative Yuan.

solves the last mile transportation problem of 67 rural areas in Taiwan, [3]thereby safeguarding the basic mobility rights of rural residents.

1-6. Close education gap: Develop an individual learning support program (ILSP) and digital learning after-school study buddy program for students, and use technology to help underperforming students.

1-7. Wisdom of the crowd: Build a social innovation observation platform which uses civic technology to collect community plans and progress; and integrate real-time data to provide citizens with access to resources and data. Improve the public's literacy of ICT and Appropriate Technologies, and enhance data application capability of civic groups across Taiwan so that digitally competent members can apply digital and data technology to diagnose community needs and use appropriate technology for the benefit of the general public.

Goal 2: Invest in basic scientific research, promote R&D of technologies in response to the needs of society, and promote inter-ministerial collaboration with appropriate resource allocation on mid- and long-term development of key technologies and unmet needs

To distribute S&T resources evenly, while steadily promoting mid/long-term development in science and technology, the government needs to ramp up efforts in S&T areas that are important, autonomous, beneficial to the society, and valuable in the long run. It must develop a definitive S&T budgeting and performance evaluation mechanism to address unmet needs of industries and the society. This goal will be achieved by taking the following actions:

2-1. S&T development and social studies: To ensure that digital, biomedical, and net-zero transition applications stick to the principles of fairness and impartiality for socioeconomic development, the government must engage in and

[3]Executive Yuan (2018), Executive Yuan Gazette. Referring to the definition of remote areas in the footnotes: towns or cities with a population density lower than one-fifth of the national average population density; or islands located more than 7.5 kilometers away from the municipality or county government seat. Retrieved from: https://law.moea.gov.tw/Download.ashx?FileID=94921.

deepen science, technology and society (STS) studies by establishing an STS research center that connects academic community across universities, so as to strengthen the integration of science, technology, and cultural arts in everyday life, and cultivate a pool of talents across different generations. The government should address any possible ethical impact of S&T applications by formulating laws and regulations to develop a sound ecosystem for industrial development, while creating a system that ensures social security and evaluates social, economic, and political impacts, which is then used to systematically conduct frontier research and produce evidence-based policy recommendations that are innovative and substantively beneficial.

2-2. National strategies for international cooperation on science and technology: Establish a cross-ministry collaboration platform for international cooperation on science and technology, calibrate the goals of strategies for international cooperation and integrate resources of relevant ministries, select key research topics for international cooperation according to Taiwan's mid/long-term development strategy, properly allocate resources, and engage in transnational scientific research projects jointly with friendly democratic countries such as the United States, Japan, and the European Union.

2-3. Budget for S&T to respond to the overall consensus on social development: The government expects to allocate at least 5% of the S&T budget for social development, and mobilize all members of the society to participate in the discussion of the nation's S&T development, which will uncover the unmet needs of the society and key technologies required. Through cross-ministry collaboration, a mechanism for dialogs on diverse needs will be established to collect ideas on ways to use technology to address current societal needs, such as the need for solutions to the dwindling birth rate and aging population, the need to improve self-sufficiency in resource and energy, and the need for large-scale disaster response and recovery. S&T projects whose social benefits outweigh economic benefits will be funded, and rewards and incentives based on target achievement will be provided to encourage investments from the business sector. Civic engagement mechanism will be adopted to solve major social problems.

2-4. Mid/long-term allocation of S&T budget: 20–30% (roughly NT$25–40 billion) of cross-ministry mid/long-term S&T budgets will be allocated, with goal-oriented performance evaluation based on target achievement and an exit mechanism to ensure proper allocation and efficiency of resources for key technologies. Based on rigorous evidence-based analysis, the government intends to establish a mechanism for topic selection and competency evaluation to identify frontier technologies that best meet the interests of national development in the next 10–15 years, including semiconductors, cybersecurity, space technology, artificial intelligence, biomedicine, and neuroscience.

2-5. Invest in high-value scientific research on long-term frontier technologies: Invest in, instead of funding, high-value scientific R&D projects and incorporate a profit sharing mechanism; provide incentives that will attract friendly and credible international teams or capital to participate in the research and development of long-range high-value technologies that are strategically needed in Taiwan, such as satellite, quantum computer, and precision health; and support the fast startup verification of technologies that have potential so as to attract domestic and foreign investments in the commercialization and application of high-value scientific research results.

Goal 3: Build an ecosystem of scientific research on civil-military dual-use technology, integrate the scientific research capacities of both public and private sectors, and develop cutting-edge strategic technologies and an independent national defense industry

To dissolve threats from multiple sources, both inside and outside, we need to leverage governmental resources to actively develop autonomous strategic technologies by introducing innovative technologies and efficacy from the private sector. The government aims to review the current status of S&T development, define which technologies should be focused, strengthen the cooperation mechanism in relation to demand, R&D, and manufacturing between the public and private sectors, so as to forge an asymmetrical military force that will bolster the competitiveness of Taiwan's national defense industry.

This goal will be achieved by the following actions:

3-1. Enhance the ability to autonomously conduct research on national defense technologies: Utilize a civil-military dual-use technology collaboration platform to promote industry–academia collaboration on dual-use technology and ramp up research efforts on key technologies, so as to improve the nation's capability in strategic technologies, and assist industries to obtain international certifications, thereby helping Taiwan to be a part of the defense supply chain.

3-2. Improve the government's ability to combat cognitive warfare: Promote a public–private collaboration fact-checking mechanism, develop AI-oriented network and communication technologies for military and civilian use, and empower citizens to strengthen their media literacy, thereby responding instantly to misinformation and prejudiced public opinions, and ensuring the public's will to defend democracy.

3-3. Boost innovation in energy resource technology: Develop decarbonization technology for low-carbon power supply system, and develop new technologies for renewable energies and low-carbon energies; improve technological deployment to produce green hydrogen locally from green electricity that cannot be dispatched, to develop advanced technologies for hydrogen and ammonia production, transportation, and storage, and to strengthen hydrogen/ammonia supply chains and energy security.

3-4. Develop high-tech and emerging communication technologies: Plan roadmap for the development and applications of unmanned vehicle technologies, and expand the deployment of unmanned vehicle (including air, water surface, underwater, and land) technologies and industries by combining the innovation and manufacturing technologies of industry, public, academic, and research sectors, and strengthening mechanisms of R&D subsidies, sandbox, industry–academic–research centers, and government procurement to promote the development of the unmanned vehicle industry.

3-5. Enhance autonomy in the national defense industry: Develop smart national defense capability and industry, strengthen research and talent development in artificial intelligence, and integrate technology and manufacturing capacity of the private sector in big data, IoT, 5G technology, and ICT, through a civil-military dual-use technology cooperation mechanism.

Goal 4: Build an open, secure, and trustworthy data governance system, and promote people-centered interdisciplinary S&T research

To facilitate the development of a people-centered data ecosystem and accelerate data-driven innovation and scientific research, a comprehensive data governance system that emphasizes both openness and security should be established, creating a trustworthy environment for data-driven innovation. This goal will be achieved by the following actions:

4-1. Establish a national data governance system: Formulate a national-level data strategy policy that explicitly outline the objectives, implementation pathways, and promotion methods for data openness, utilization, and supervision. Select critical topic such as net zero, greening, education, and health care as targeted area for data governance development in the current phase. Build data governance-related systems to effectively harness the key value of data in public governance and social development.

4-2. Facilitate trustworthy research data management: Build a research data platform with the goal of open science, where research projects funded by government budgets are expected to contribute over 50% of their related data back to the government. Establish mechanisms for research data openness and reuse, and ensure research data adheres to the principles of accessibility, interoperability, and reusability, so as to avoid duplication and waste of research resources and enable the reuse of government-funded research results and data for the benefit of the public and social wellbeing.

4-3. Improve the legal framework for health data utilization: The current mechanisms and legal basis for the use of health-related databases in Taiwan remain unclear. A system and regulatory framework for health data utilization will be established to enable the safe and secure use of health data, thereby leveraging Taiwan's advantages of health data to build a biomedically resilient homeland and become an international hub for precision health.

4-4. Promote sustainable AI development: Establish data governance and management rules for artificial intelligence to create a foundational environment for data governance for the R&D and application of AI technology, and strengthen data application compliance and regulatory mechanisms to achieve trustworthy, fair, and interpretable AI data governance. Develop the data ecosystem needed for AI to foster a virtuous cycle of AI development.

Goal 5: Accelerate digital transformation and net-zero transition of all industries, and develop a novel framework of technology industries that links to startup ecosystems so as to promote balanced regional development and international competitiveness

Promoting digital transformation and net-zero transition across industries is an integral part of the government's long-term S&T policy. As the crucial hubs of major S&T innovations in Taiwan, science parks not only bring science industries into the spotlight of international trade, but also serve as a core connection point for regional human resources, industrial activities, and innovative applications. In the future, science parks will have more diversified capabilities to link and integrate their neighboring industrial parks and innovation bases, drive the digital transformation and net-zero transition of surrounding systems, operate through a new type of circular economy model, and foster a symbiotic living system with the neighboring residents. This goal will be achieved by taking the following actions:

5-1. Establish a connected startup ecosystems: Develop a digital and net-zero transition system for industries in science parks, create an ecosystem consisting of the related industries, and introduce innovative software services to enhance digital and innovation capabilities with the hope of translating future key technology R&D outcomes into startup businesses in various science parks to help solve issues that will affect future park operations, such as low-carbon transportation, cybersecurity management, and green energy supply.

5-2. Strategies for accelerating dual transformation: Promote digital transformation and net-zero transition, starting with key businesses to small and medium-sized enterprises (SMEs), and ensure the sustainable development of these key businesses and their systems under the dual transformation trend. For example, establish a decentralized green energy digital management system with park-level energy storage and renewable energy systems at its core, to build a virtual power plant in the science parks and thus to ensure uninterrupted production for critical S&T industries.

5-3. Speed up the development of circular technology: Introduce green, circular designs and recycling concepts to develop products that can be disassembled, recycled, and reused to reduce waste. Effectively utilize surplus energy and resources generated during the production process (including by-products or waste) reuse them by using remanufacturing methods. Consider future scenarios in which energy or resource supply is limited, and focus on the R&D of green energy technologies, products or equipment that incorporate alternative materials or use alternative resource processes.

5-4. Engage in local Smart City development: Encourage science parks to actively participate in local smart city initiatives that promote the balanced regional development. Seize opportunities for exchange in smart urban–rural development initiatives to help science parks forge international ties, which will create more opportunities for park members to participate in international pilot projects.

Goal 6: Set up, maintain, operate, and develop infrastructures for a resilient society with both hardware and software, enhance agile response systems for future risk management

As Taiwan faces high levels of uncertainty in areas such as societal and economic security in the future, it is imperative to anticipate and mitigate potential impact and risks through early investment in technology. The government must therefore invest in frontier software and hardware technologies to reinforce the stable operational capability of various key infrastructures, thereby enhancing societal resilience and securing our country’s ability to respond to various risk issues. This goal will be achieved by taking the following actions:

6-1. Strengthen economic and supply chain resilience: Establish a transnational geopolitical risk data assessment database and at the same time, track the supply and demand changes of raw materials and components in various key industries, so as to assess supply chain risks in real time and provide recommendations accordingly. Build a smart key infrastructure and strengthen the capability of domestic industries to manufacture and produce key materials. Establish a circular economy system for recycling and reuse, and reduce dependence on the international supply of important raw materials and therefore enhance the resilience of our country's supply chain autonomy.

6-2. Enhance the resilience of energy systems: Develop the capability to develop new energy sources independently, carry out R&D works on energy storage and hydrogen conversion systems so that hydrogen will account for at least 10% of Taiwan's energy mix in the future. Conduct research on innovative energy storage materials to meet our country's needs of large amount of energy storage in the future.

6-3. Create a daily life risk map for the citizens: Create a daily life risk map that civilians will face in their everyday life by compiling risk information from data platforms across various regions, such as environmental pollution (noise, air, water, ocean), crime hotspots, and frequency of accidents, and present it in the form of integrated risk assessment to help the citizens from different areas to respond to risks more effectively and reduce the probability of risks or accidents.

6-4. Develop backup network technologies: Continuously expand the international communication network backup system. Strengthen our capabilities to identify and defend against cyberattacks through backup communication network systems which feature asynchronous communication satellite and optical cable technology. Maintain the quality of communication and mobilization capabilities among various societal sectors, and promote cooperative innovation among strategic industries in Taiwan and form a crucial basis for emerging S&T industries in the future.

6-5. Maintenance, management, and research of ocean space: Establish a cross-ministerial strategic map of Taiwan's marine environment (hydrology, geology, geology, ecology, etc.), and develop a resilient ocean/sea environment so as to assist Taiwan in maintaining the continuous operation of important systems such as offshore wind power and submarine cables and reduce risks of power and international communication interruptions due to disasters. In addition, actively initiate research investigations on ocean energy, seabed minerals, and seawater hydrogen to identify alternative resources in the event that access to crucial resources is blocked.

6-6. Integrated application of smart patrol, sensor, and IoT technologies: Develop a distributed smart living real-time response system, which creates a sensor fusion environment. Integrate existing various types of sensors and IoT technologies to strengthen autonomous decision-making capabilities of various traffic signals and pipeline systems. Manage resource allocation with AI technology, which is expected to speed up disaster prevention and advance early warning time by 50%, and use sensor-integration analysis technology to integrate unmanned vehicle technology and develop precision delivery capability.

Goal 7: Promote technological innovation and transformation of the software and service industries, lead them into international markets, and establish a leading position in the industry

In 2019, the overall output value of Taiwan's digital economy accounted for approximately 19.2% of the GDP,[4] which was higher than the United States (10.6%) and South Korea (10.6%). The output value of Taiwan's digital manufacturing and digital service industries accounted for about 16% and 3.2% of GDP, respectively. These figures indicate that the digital service industry still remains to be further developed compared with digital manufacturing. To strengthen the socioeconomic contribution of the digital service industry, cybersecurity and additional investments in the development of new software

[4]Information Service Industry Association of R.O.C., 2022 White Paper on Information Service Industry, retrieved from https://www.cisanet.org.tw/News/Detail/5589.

technologies (e.g., AI, XR[5], and blockchain) and talents are equally important. Moreover, the government must keep promoting the cultivation and operation of digital platforms and subsequently ramp up efforts to strengthen and expand business opportunities from various digital software application services such as smart manufacturing export services, tourism, retail, healthcare, and emerging technology platforms. This will in turn drive the innovation and development of software and service industries in Taiwan, thereby pushing the digital service and software industry into global spotlight while also prompting a pay rise in relevant industries in Taiwan. This goal will be achieved by taking the following actions:

7-1. Smart manufacturing service exports: Enhance the capacity of software and information services, assist the manufacturing sector in analyzing and predicting customer demand trends so as to keep abreast of customer demands in overseas niche markets, and motivate manufacturers and digital service providers to jointly create a business model that establishes a global presence for smart manufacturing services, thereby raising the pay level of the industry. It is hoped that within four years, export services will cover more than 50% of the expected output value of industries associated with manufacturing, and the wages of the domestic manufacturing service industry will increase by more than 10%.

7-2. Strengthen cybersecurity for software and hardware services: Establish an internationally recognized cybersecurity certification framework while also developing cybersecurity-certified software, coupled with professional third-party audits to be a benchmark for the international development of Taiwan-based cybersecurity companies. In the meantime, continue to improve the platforms already built by current technology R&D projects, introduce foreign capital for specific service items and contents, jointly set up cybersecurity venture capital funds, and build an international cooperation platform, which will be used to lead investment and guide domestic cybersecurity-certified companies to meet international standards. By doing so, we expect to have more than three internationally recognized cybersecurity service providers within four years, thereby enhancing cybersecurity resilience and the information security of

[5]XR encompasses augmented reality (AR), virtual reality (VR), and mixed reality (MR).

various industries, and improving the service capacity and promoting the export capability of Taiwan's cybersecurity industry.

7-3. Promote international tourism to boost local retail service industries, thus raising employment wages: Create online experiences that demonstrate the unique characteristics of tourist attractions in Taiwan to attract and entice international tourists to visit and experience Taiwan on-site, such as cycling, hiking, bird watching, food, biodiversity, and local cultures. Improve digital technology capabilities of regional retailers and tourism service providers (e.g., smart translation and virtual tour guide services) to keep abreast of tourist needs, which will then help them strengthen their shopping tourism strategy, improve the quality of their online and offline services, and increase tourist revisits. The number of international tourists is projected to be restored to pre-pandemic levels (11 million tourists in 2019)[6] within two years, and the salary of service-sector employees will therefore be increased by more than 5% within four years.

Goal 8: Make the most of digital technology in innovation and develop cutting-edge technologies in order to upgrade manufacturing sector, develop advanced manufacturing hubs and next-generation manufacturing industries

To accelerate industrial innovation and development, the government must continue to tap into the strengths of Taiwan—that is, its digital technology and fast integration capability, to optimize and upgrade the core facilities and service platforms required for the development of cutting-edge technology, and by using the existing capabilities of the semiconductor industry, upgrade the industries in Taiwan and steer them towards next-generation high-end manufacturing. This goal will be achieved by taking the following actions:

8-1. Diffuse the benefits of the semiconductor industry: Integrate the existing capabilities of the semiconductor industry into food, clothing, hospitality, travel, education, and entertainment industries, and build and promote a mechanism for

[6]Taiwan Tourism Bureau, Ministry of Transportation and Communications, 2022 Tourism Statistics Database of the Taiwan Tourism Bureau, retrieved from https://stat.taiwan.net.tw/statistics/year/inbound/purpose.

the semiconductor industry to cooperate with emerging industries, so as to develop industrial clusters or chains in smart agriculture, precision health, metaverse, smart electric vehicles, next-generation communications, and smart manufacturing. Accelerate the vertical integration of semiconductors and industrial application, and help the emerging industries grow rapidly with the advantages and capacity of the semiconductor industry.

8-2. Strengthen international leadership in next-generation scientific research: Establish an internationally recognized base that develops the practical application of next-generation strategic technologies and provide a world-class infrastructure where the resources of key industries are leveraged. This base will in turn attract international R&D professionals to work in Taiwan and contribute to the development and value-added applications in semiconductors and quantum technologies, thereby increasing the autonomy and international status of Taiwan in next-generation strategic technologies.

8-3. Link the world's digital capability: Shift from single-point entry to nationwide expansion, urge major international manufacturers to establish their R&D base and digital platforms, conduct R&D, and carry out talent training in Taiwan. Guide upstream and downstream suppliers in Taiwan to connect their platforms or form a network of systems, with Taiwan as the test base and the starting point of supply chain integration so as to transform Taiwan into an integrated cluster of advanced manufacturing supply chains of democratic countries.

8-4. Adopt new-generation smart manufacturing model: Help SMEs adopt smart manufacturing and Digital Twins in smart physical and virtual factories by establishing digital platforms among other measures that will help companies quickly learn and achieve "intelligent operation prediction and decision-making", “real-time remote collaboration”, “global uninterrupted operation”, and “fully-linked production and global supply chain scheduling”, all of which contribute to the realization of a new smart manufacturing model for lights-out factories around the world. Specifically, the objectives are to help 15,000 (10%) manufacturers engage in high-end manufacturing, assist with industry upgrades, and enhance international competitiveness.

Goal 9: Create a comprehensive diplomatic strategy that is driven by democracy and technology

As the future geopolitical landscape will highly likely be dominated by competition between democratic and authoritarian camps, Taiwan has become a trusted and indispensable partner within the democracy bloc. By integrating Taiwan's development experiences and strengths of scientific research, the government proposes a comprehensive S&T diplomatic strategy, which takes democratic values as the foundation of international connections, and leverages technological advantages to create cooperative benefits and gain support and collaboration from allies. This goal will be achieved by taking the following actions:

9-1. Plan a comprehensive geopolitical strategy for technology: Rapid geopolitical changes around the world further underline the roles and importance of science and technology. S&T development, in general, contributes to national security, the deepening and consolidation of democracy, and world peace. To strengthen this contribution, the government will create a comprehensive diplomatic strategy that is driven by democracy and technology in order to plan a national strategy for geopolitical technology.

9-2. Strengthen national security through S&T development: Strengthen laws and regulations and civil society, safeguard Taiwan's critical technologies, consolidate and deepen democracy with technology applications, establish technology-driven diplomacy, and build a strategic map for the development of key technologies and national security.

9-3. Leverage S&T diplomacy to fortify international ties: Strive to establish research organizations in democratic countries, encourage Taiwanese scholars to engage in international cooperation and exchange, attract foreign professionals to work in Taiwan, and build a friendly living environment by reviewing immigration and employment policies, so as to promote two-way flow of talents.

9-4. Develop an S&T security governance mechanism: Help industries establish a cybersecurity certification mechanism, such as the Cybersecurity Maturity Model Certification (CMMC) program introduced by the U.S. Department of Defense, or a mechanism for the standardization of S&T products, security certification, and supervision systems. Take advantage of the international trust that Taiwan has gained, and actively participate in the S&T initiatives and alliances of democratic countries by joining the U.S. Clean Network or signing the US-Taiwan Initiative on 21st-Century Trade.

Goal 10: Promote open and innovative talent development and vocational training to respond to Just Transition

As technology propels economic and societal transformation and development, people may lose their jobs or need to upskill due to human labor being replaced by intelligent machinery in industrial transformation. Therefore, the government needs to provide guidance and assistance in digital learning, technical education, or vocational training. By applying technology in the open innovation of talent development and vocational training systems, we can establish a fully connected dynamic learning system that encompasses the entire life cycle, and facilitate the mutually beneficial development of talents and industries so as to achieve a just transition in society. This goal will be achieved by taking the following actions:

10-1. Increase the value of talent sustainably: Establish a record of talent life cycle based on learning trajectory analysis so as to help talents continue to demonstrate their value to the labor market. With the introduction of AI and net-zero policies into industries, around 1.49 million middle-aged and elderly blue-collar workers in our country could be affected. The government therefore needs to be proactive in customizing career plans for these workers and train them to obtain digital skills or certifications, or increase productivity through human–machine collaboration to meet the needs of corresponding industries. The government needs to establish the My Data platform that provides accessible data on labor supply and demand in order to create friendly work environment. The government must establish incentives by using time bank or virtual currencies, encourage continuous participation by retirees, and appoint professionals to teach and show them how it is done, thereby sustaining the value of talented professionals to mitigate the impact of labor shortage.

10-2. Provide overseas talent recruitment channels: To date, a total of 500,000 Taiwanese nationals are working overseas[7], of which 252,000 are the primary working force aged between 30–49 years old, and 390,000 have a university degree or above. In addition, there are 20,000 Taiwanese students studying abroad. In face of talent drain,[8] the government must provide channels for recruiting overseas Taiwanese talents and offer remote work opportunities to attract and connect with talents to increase their intention to return and work in Taiwan. The government needs to establish a lifelong mechanism to observe talent mobility, cultivate a community of talents and provide them with employment and living assistance in Taiwan, and improve the living and childcare environment to perfect talent recruitment and retention.

[7]Directorate General of Budget, Accounting and Statistics (DGBAS) of Executive Yuan (2022), National Statistics, retrieved from https://reurl.cc/LXaaEK.

[8]Department of International and Cross-Strait Education, Ministry of Education (2022), 2011─2020 Statistics on the Number of Taiwanese Students Studying Abroad with Student Visa, retrieved from https://reurl.cc/ERMmVv.

04

Chapter 4

S&T Development Strategies and Measures

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4.1 Inclusive and Fair Society

Science and technology should be developed in the spirit of meeting people's needs to promote national health and well-being, a respectful and inclusive attitude toward all cultures and ethnicity, and social contribution. Social science research exhibits the forward-thinking value of technology, creates an environment for the development of different ethnic groups, provides each person with the opportunity to learn and unleash their skills, leads to the development of flexible, diverse educational systems that foster co-participation capability, and safeguards national security. In transitioning toward net-zero emissions, needs must be analyzed and managed through institutional innovation to achieve inclusivity where costs and burdens are shared. The general public or social organizations should work collectively to co-create a society that is resilient to energy transition and digital transformation.

An inclusive and fair society is associated with three issues: social security and gender/racial equality; net-zero life and just transition; and interdisciplinary talent development, labor market transformation, and economic equality. The problems and challenges of each issue and counterstrategies are described below.

4.1.1 Social Security and Gender/Racial Equality

(1) Problems and challenges

A. The intention of women to work in scientific research and their opportunity for job promotion are affected by social and cultural values and family care factors after reaching adulthood

Because of social and cultural values, women are not as inclined as men to choose to study and work in the STEM field. According to statistics on the fields of study of higher education students in 2014–2016 published by the United Nations Education Scientific and Cultural Organization (UNESCO)[9] and statistical data on universities and colleges for the academic year 2015 (August 2015–July 2016) provided by the

[9]UNESCO (2017). Cracking the code: girls' and women's education in science, technology, engineering and mathematics (STEM). Retrieved from https://reurl.cc/LXKd0y.

Ministry of Education of Taiwan[10], within the female student population in higher education globally (in Taiwan), 55% (35%) chose natural science, mathematics and statistics; 28% (32%) were enrolled in ICT; and 27% (15%) chose engineering, manufacturing and construction. In comparing the percentage of male and female students in higher education by STEM-related fields of study in the academic year 2021 in Taiwan[11] (August 2021–July 2022), gender differences by fields of study: natural science, mathematics and statistics, ICT, and engineering, manufacturing and construction were 15%, 44%, and 60%, respectively. These results show significant gender differences in Taiwan regarding the intention to choose STEM-related fields of study in higher education.

Women, after marriage and childbirth, typically leave employment earlier or temporarily following childbirth because of traditional family views and family care responsibilities. Consequently, the labor force participation rate among women aged 45–49 years has decreased considerably in recent years, resulting in negative growth in the labor population. According to data published by the U.S. Bureau of Labor Statistics in September 2022[12], demand for STEM employment will increase by 10% by 2031, which is twice the demand for non-STEM employment (4.9%). If the labor participation rate among women continues to fall, STEM-related fields will face labor shortage problems in the future, affecting socioeconomic development.

In addition, the ratio of men to women who worked as senior managers in companies of more than a hundred people was 9:1. In terms of industry, male managers accounted for 95% of the manager population in electronic/information/software/semiconductor, general manufacturing, and transportation, logistics and warehousing industries. In the field of R&D, nearly 100% of managers are all male. According to research, marriage and childbirth events anticipated for female students in medical

[10]Department of Statistics, Ministry of Education. Summary Data of Gender Statistical Indicators. Retrieved from https://reurl.cc/Ayvgjd.
[11]Same as Footnote 2.
[12]U.S. Bureau of Labor Statistics, retrieved from: https://www.bls.gov/emp/tables/stem-employment.htm.

school negatively influence their possibility of becoming managers in the future, whereas no significant change is anticipated for male students after marriage or childbirth [13]. This phenomenon shows the difference in treatment in workplace promotion for women. In other words, the career development of women in professional fields such as scientific research may be limited by education, family care responsibilities, differences in salary and job promotion opportunities, and lack of sense of belonging to the field, thereby causing a loss of female scientific researchers from the scientific research system.

B. Population aging and the dwindling birth rate will worsen the problem of a shortage of elderly and infant caregivers

The surge in the aging population will further increase the demand for long-term care for elderly adults and infants. According to the 2021 Population Statistics published by the Ministry of Interior on January 10, 2022, as of December 2021, Taiwan registered a total of 153,820 births for 2021, a record low. There were 11,429 fewer births (–6.92%) than in 2020. Therefore, the low birth rate problem is persisting, and childcare assistance must be proposed to encourage childbirth. With respect to long-term care, the population in Taiwan is aging rapidly, with super-agers (>85 years old) accounting for 10.7% of the elderly population in 2020, which is projected to reach 27.4% by 2070. In 2017, approximately 577,000 people needed long-term care in Taiwan; this number is projected to increase to more than 770,000 people by 2026. The Department of Statistics, Ministry of Health and Welfare reported that Taiwan had, on average, 21.7 Western medicine physicians (or 31.3 including Traditional Chinese Medicine physicians) in a population of 10,000 people in 2020[14], which is lower than the median of 34.3 physicians in members countries of the Organization for Economic Cooperation and Development (OECD).

[13] Dissertation published by October 2017 by Professor Chien-Chou Chen from the Department of Medical Sociology and Social Work, Kaohsiung Medical University, titled Gender in Medicine: Constructing Interdisciplinary Teaching and Teaching Innovation Research of Medicine, Humanities and Gender Education—Differences in Career Imagination Between Male and Female Medical Students and Influencing Factors.

[14] Ministry of Health and Welfare (2021), Physician Statistics, retrieved from https://www.mohw.gov.tw/dl-72644-98674809-7c6d-475d-8cb7-2fb1638a6b2b.html.

These trends reveal that the shortage of care labor and medical resources is an imminent problem for Taiwan. Moreover, taking care of elderly adults for a long period causes occupational injuries to caregivers, which will further widen the caregiver gap. In view of this, the Ministry of Health and Welfare predicted that the nursing gap in Taiwan will reach 15,000–24,000 people by 2024.

C. Various ethnic cultures and languages are facing endangerment and extinction

Taiwan is characterized by a multicultural society in which there exist many ethnicities and languages. However, the indigenous peoples of Taiwan are facing cultural endangerment, with local cultural identities such as traditions, languages particularly native languages, and customs fading fast. According to UNESCO's 2011 Atlas of the World's Languages in Danger, 7 indigenous languages in Taiwan are endangered and 8 have become extinct. Therefore, cultural equality and cultural accessibility are key to the cultural preservation of various cultural groups (new immigrants, Hakkas, and indigenous people), which ensures equal rights to cultural enjoyment, thereby avoiding differential treatment. The co-existence and mutual prosperity of different cultural contexts to safeguard cultural diversity and promote diversification are fundamental to the cultural development of Taiwan.

D. Lack of transport accessibility and unique geographical and cultural characteristics of remote rural areas are the cause of the uneven distribution of medical, daily, employment, and educational resources, which affects the long-term development of a society

Rural areas in Taiwan are characterized by poor road conditions, scant population, and transport inaccessibility, all of which add to the inconvenience of local residents in various aspects of daily living, such as health care, work, education, and commute, resulting in unequal mobility rights. Furthermore, rural areas have a high population of elderly people who have a greater need to seek medical attention. However, due to limited healthcare resources in rural areas, older adults urgently need convenient transportation to seek medical attention in cities. According to the Taiwan Medical Association's report[15] on the number of physicians across counties and cities in 2021, Kinmen only has an average of 6.7 physicians (the least) per 10,000 population, whereas Taipei City has 45.9 physicians (the highest) per 10,000 population. In terms of area, there are 0.09 physicians per km^2 of Taitung County and 42.6 physicians per km^2 of Taipei City, a 473-fold difference. Access to medical treatment also takes longer for rural residents because of inconvenient transport. A single trip to medical services in urban areas takes over an hour, making it more difficult for people in remote areas to seek medical treatment.

Medical access, daily activities, and shopping in rural areas are affected by geographical location and distance, resulting in poor infrastructures with respect to activities of daily living, education, employment, and healthcare, as well as uneven distribution of resources. These factors will lead to an exodus of population, socioeconomic problems, and public security concerns, affecting social development in the long run.

E. Critical illness reporting requires real-time integration, and drug supplies are unstable

The impact of COVID-19 will persist and continue to spread in the short term. Aspects relating to pandemic prevention such as the diagnosis and reporting of critical infectious diseases, medical treatment, supplies, and vaccinations must be integrated using technology into real-time information systems and early monitoring and risk warning mechanisms for infectious diseases. The outbreak of COVID-19 and monkeypox in recent years has revealed the unpredictable nature of infectious diseases. With the gradual opening of international tourism and frequent business dealings across borders, the research and development of vaccines and drugs should no longer be limited to a few critical diseases only; the scope of research must be expanded and defined further.

The globalization of drug supply chains has made the deployment of

[15]Taiwan Medical Association (2022). Number of physicians practicing in counties/cities, population size, area, number of people served by each physician, number of physicians per square kilometer. Retrieved from https://reurl.cc/mZxxa1.

global drug supplies susceptible to any supply chain disruptions. Taiwan will be facing a medicine shortage because of its dependency on imported drugs or materials, especially when the supply chain is easily affected by external factors such as the pandemic, shipping, and war. Regarding drug information, hospitals in Taiwan are taking their own inventory of drug usage and safety; therefore, there is still a need to adopt and integrate domestic drug supply information systems, information security systems, and relevant mobile information technologies.

F. Extreme climate events cause water shortages, unstable power supply, and challenges in submarine cable deployment

Extreme weather and disaster events are becoming more frequent. Even though the government has ramped up disaster risk management, problems and challenges are still awaiting solutions. The Ministry of Economic Affairs speculated that swift actions are necessary; otherwise, Taiwan may face a daily shortage of 116,000 tons of water nationwide by 2031.[16] In terms of power supply, the power outage on March 3, 2021, affected the progress of factory production in the S&T sector, resulting in tens of billions of losses for the sector. The loss in the overall economy was difficult to estimate. As for communication cables, submarine cable stations in Taiwan are mostly concentrated in the north, causing the risk of cable overconcentration. Moreover, the uneven distribution of submarine cable resources threatens the communication security of submarine cables in Taiwan.

(2) Response Strategies

A. Promote gender equality, create a gender-friendly environment, increase the intention of women to work and engage in S&T development

(A) Create a work environment in environmental, energy, and S&T fields that is conducive to women's careers (employment, job promotion, and development) and that facilitates gendered scientific study,

[16]Ministry of Economic Affairs (2018), Action Plan on Stable Water Supply Strategies for Industries, retrieved from https://www.wra.gov.tw/cl.aspx?n=113.

technological R&D, and universal design research.

(B) Promote the rights and interests of women when they participate in education and programs, hiring process, expert panels, or other representative activities in STEM-related fields.

(C) Adopt gender perspective into climate adaptation and mitigation measures, infrastructure, living space, and urban and rural environmental planning to incorporate the basic needs of people of different genders.

(D) Perform analysis from both the perspective of sex and gender in S&T development to promote innovation in S&T knowledge.

(E) Create a female-friendly career development environment under the premise that rules and the environment fully protect labor rights; use a platform-based economic model to provide unemployed women with flexible job opportunities; employ online platforms to teach women content creation, use of technology, and product marketing; and offer flexible learning and certification-obtaining opportunities through Internet courses to improve problems that women face when searching for jobs, strengthen women's economic empowerment and independence, and achieve a fair distribution of economic resources.

(F) Expand the provision of welfare resources such as childcare, public education, and social security to create a female-friendly career development environment; and achieve gender equality by enforcing laws and regulations that eliminate discriminatory treatments in the workplace and help increase women's access to leadership positions.

(G) Include STEM in education for infants and basic education; set up STEM-related social club activities, encourage women to participate in these activities, and monitor the effectiveness of these activities; offer awards and funding that encourage female researchers to engage in scientific research in order to support the development of female researchers in the field of science and cultivate more talented female scientists, thereby bolstering Taiwan's competitiveness in S&T development.

B. Technology-driven care for elderly people and children hails a new era of smart health care, enhancing national health and care

(A) Promote gender equality and health and care jobs, adopt affordable and people-centered care assistive technology (caregiving robot, smart position setting, wearable and non-wearable smart mobility devices), and reduce occupational injury among personal care attendant so as to extend their years of service, and improve quality of care provided to elderly people with disabilities.

(B) Address the needs of society through the development of appropriate technologies and develop technological tools that integrate a gender perspective and align with social development; for example, adopt AI technology and promote a new medical consultation model such as virtual (remote) consultation, smart care devices for babies and infants, and other emerging technologies to improve the shortage of healthcare workers.

(C) For suboptimal health populations, install or set up activity tracker devices in individual health-monitoring wristbands/mobile phones and in sports grounds, develop a mechanism that actively reminds individuals about their physical activity and health conditions, and guide citizens to monitor their activity level and physical health voluntarily; implementing these measures over the long term can enhance national health and reduce national health insurance expenditures.

C. Promote local cultural assets and balance urban–rural resources to achieve cultural equality

(A) Provide public access to the public sector’s digital archive data collection and develop user-friendly data interface and application software programs to increase the right of the public to access digital cultural content; build a digital curation platform and encourage people and civic groups of varying social backgrounds (indigenous groups, new immigrants, adolescents, and female) to use low-threshold and user-friendly civic curation software systems to demonstrate the experience and cultural characteristics of different social groups; and organize an animated digital portal to Taiwan to show the world the brilliant multicultural characteristics of Taiwan.

(B) Adopt technology to promote the production of local, native cultural content so that culture is accessible to everyone—a real-life example: Over 500 art museums around the world have cooperated with Google between 2011 and 2022 to develop an online museum, Google Arts & Culture, which uses Google Street View to capture places and exhibits inside museums, bringing arts and cultures online.

(C) Break the antithesis between traditional culture and modern capability/knowledge by integrating cultural contents into teaching, such as knowledge building or knowledge in environmental education to promote the integration of local traditional culture and modern capability.

D. Strengthen rural transport infrastructure to construct a digital and inclusive society

Incorporate a device positioning and vehicle pick-up technology platform, which adopts user-friendly models for rural and elderly residents, is made more flexible through regulatory amendments by the Ministry of Transportation and Communications, and combines innovative cooperative economic organizations to establish a point-to-point comprehensive pick-up service that solves the last mile problem of 67 rural areas in Taiwan, thereby safeguarding the basic mobility rights of rural residents.

E. Strengthen biotechnology and pharmaceutical technologies and R&D mechanism to enhance national capability in pandemic prevention and public health

(A) Integrate resources across ministries to improve pandemic prevention platforms, develop an overarching national pandemic prevention decision-making support system, and leverage the expertise of government-associated think tanks to analyze various pandemic-related data from Taiwan and overseas and to assist with the flexible adjustment of policies while engaging in transnational comparison to learn from the successful experiences of other countries.

(B) Maintain the operation of new viral technology support platforms and infectious biomaterials, connect to mechanisms that the academic, research and industrial sectors use to confirm and coordinate specimen needs, accelerate authorization and pilot mass production procedures for product inspection in Taiwan, and assist with the development of antiviral drugs, vaccines, and rapid antigen tests and other products in Taiwan to achieve early preparation and expansion of pandemic prevention capabilities.

(C) Provide a more efficient, transparent shortage reporting and inquiry platform by setting up a "drug usage" monitoring platform; commit to the research and development of new vaccines, medications, and biomedical technologies, develop precision health treatment drugs and expand their scope of application to biotechnology, actively support innovative research and attract input from the industrial sector, develop a complete supply chain comprising industrial, academic, research, and healthcare sectors in order to accelerate the commercialization of novel drugs in Taiwan; actively seek to join international platforms so that key drugs, generic drugs, and biotechnology products can be developed collaboratively to bolster Taiwan's pharmaceutical and biomedical R&D capability and efficiency and address drug supply problems and needs for industrial development.

F. Bolster the resilience of infrastructures through technology to enable more flexible responses

(A) Apply 5G, ICT, AIoT, and other digital technologies to continuously strengthen water monitoring, water source deployment, and water management, expand new sources of water, economize water, deploy supplies, and create backup networks, thereby improving water efficiency and deployment and backup capacities in order to prepare for the impact of climate change and ensure water supply.

(B) Use technology to develop a sound electricity system, including power grids, and smart electric meters, and a distributed grid and regional deployment center that enables Taiwan to more flexibly tackle extreme risks more and quickly restore power through regional backup generator systems and real-time deployment.

(C) Reinforce the resilience of electricity systems by using scientific, objective, and quantitative results of the power grid and energy supply facility risk quantification and assessments to optimize power supply stability, risk control, and distribution of economic resources.

(D) Avoid excessive centralization of fiber optic backbone technology to strengthen regional network performance and establish a national undersea cable repair fleet to reinforce disaster response capability.

4.1.2 Net-Zero Life and Just Transition

(1) Problems and Challenges

A. Transitioning to a low-carbon, net-zero life triggers energy costs and green spending that may increase public expenditure; policies and communication strategies must be planned to assist with the transition process

According to the Report on the Survey of Family Income and Expenditure[17], expenditures that Taiwanese families in the lowest 20% income bracket spend on transitioning to a net-zero life accounted for 62.33% of their total family expenditure, higher than the national average of 54.48%. In promoting the transition to net-zero life, daily energy and transportation expenditures and expenditures on retrofitting smart energy-saving appliances will increase in the future; this policy will have the greatest impact on low-income populations. In addition, the cost of living for the general public will increase further if electricity price increases in conjunction with the increase in the price of electric vehicles and maintenance costs.

[17]Directorate General of Budget, Accounting and Statistics, Executive Yuan (2022), 2020 Report on the Survey of Family Income and Expenditure, retrieved from: https://win.dgbas.gov.tw/fies/doc/result/109.pdf.

B. The way most of the products operate in the market is aimed at stimulating consumption, which is not conducive to a net-zero or low-carbon dietary/lifestyle

Business entities, including suppliers and manufacturers, constantly reshape consumption methods and patterns to stimulate purchase and spending behaviors to boost profits and create artificial demand. Supermarket chains encourage franchisees to increase purchase in order to generate revenue for the parent company. However, large purchases of fresh food often lead to considerable food waste. The apparel industry is moving toward fast fashion, causing consumers to replace their clothes more frequently, which results in overproduction and oversupply, waste of resources, excessive energy consumption, and a high carbon footprint.

C. Domestic demand-driven industries, such as transportation, construction, and electricity, must transform through employee upskilling during the process of transitioning to net-zero emissions

The net-zero transition will mainly impact industries involved in electricity, steel, petrochemistry, cement, and road transportation, with the road transportation sector exhibiting a lower degree of centralization, so a wider range of business operators in this sector might be affected. With respect to the impact on the road transportation industry, the continuous increase in the penetration rate of electric scooters (4% as of the end of May 2022)[18] has expanded the impact on the employment of traditional motorcycle stores (approximately 26,000 stores). Therefore, facing the growing popularity of electric vehicles, by 2040, business operators must transform their business while technicians who work for them must upskill.

D. Emission-intensive industries are affected by the EU carbon tax, which will affect exports and impact energy-intensive industries the most

As countries around the world implement carbon border tax

[18]Directorate General of Highways under the Ministry of Transportation and Communications (2022), Statistical Data Query, retrieved from https://reurl.cc/gQRelV.

mechanisms in the future, industries in Taiwan that will be affected include the manufacture of other non-metallic mineral products, the manufacture of chemicals, basic metal, and electrical/electronic industries. The impact will be equivalent to NT$75.7 billion and a loss of approximately 6,000 job opportunities. The generation of power from green energy will increase in the future, which may raise industrial electricity prices. Industries affected by the carbon border tax are energy-intensive (consuming more than 10 kWh of electricity per output of a thousand NTD), meaning that these industries will be subject to double impact, which is projected to affect roughly 115,000 employees in related industries. Therefore, in transitioning to net zero emissions, current employees must be assisted with upskilling, career transition, or re-employment.

E. Additional supply and sources of renewable electricity and resilient power grid are required in the green electricity market

Ever since Taiwan implemented the green energy wheeling mechanism in 2020, a total of 1.06 million renewable energy certificates have been issued, nearly 99% of which were purchased by Taiwan Semiconductor Manufacturing Company.[19] This phenomenon shows the unequal distribution of renewable energy between large companies, which have a strong financial position to obtain a majority of renewable electricity and SMEs. Taiwan aims to generate more than 60% of its electricity from renewable energy by 2050; this goal will inevitably expand renewable power supply, increase sources of renewable electricity, and enhance grid resilience. Therefore, high electricity users in the industrial sector should steer toward building their own power generation plant and power grid, which not only increase renewable energy supply to solve the uneven energy distribution problem but also facilitate the development of a distributed grid pathway for a more resilient power grid. Community citizens should be guided to fulfill the responsibility of transitioning to net zero emission, participate in renewable energy

[19] National Renewable Energy Certification Center, retrieved from https://www.trec.org.tw/.

development projects such as community-based power plants or the Community Renewable Energy Project, and in turn be capable of generating, distributing, and sharing electricity independently. However, distributed and smart grids are still not making headway for the following reasons: An infrastructure that transmits and distributes electricity is difficult to build; electricity prices are too low; residents are against it; old buildings are not favorable for setting up distributed power grids; and applicable laws and regulations still require an amendment to boost encouragement and defuse resistance.

F. Society in Taiwan lacks a mechanism for building solidarity among citizens to promote local sustainable development

Under the global trend of net zero emissions, companies in various countries are all required to adopt carbon reduction and low-carbon measures in their business operations and are encouraged to enter the green and circular economy niche market. In recent years, the United Kingdom has advocated adopting the concept of behavioral economics and formed policy tools that guide consumers to change their behavior. Given the issue of low-carbon net-zero transition, current international trends not only emphasize the change in consumer behavior but also underline the importance of solidarity as well as social innovation or green living in a region so that ensuring sustainable production and consumption patterns becomes a social responsibility.

(2) Response Strategies

A. Promote civic participation and advocate sustainable production and consumption patterns by developing a strategy for promoting sustainable living and consumption

(A) Switch from a professional centralization system to an open and public–private collaboration model in policy adaptation.

(B) Actively organize communities to jointly draft consumer regulations on net zero transition and develop consumer guidelines that align with the general consensus; provide for checks and balances on large companies, and enhance the behavior change literacy of the general public through industry guidance.

(C) Develop a risk disclosure platform that is easy to operate for all age groups, a sustainable living dashboard, and information on the carbon footprint of everyday activities; conduct opinion polls to educate citizens on the environment and the environmental impact of their behaviors.

(D) Adopt a behavioral science model that guides the general public to be responsible for low-carbon costs.

(E) Request merchants to provide information on product reparability, regulate product packaging, and increase the transparency of consumption information so that citizens fully comprehend their consumption behavior.

(F) Develop a lifestyle transition strategy that considers local sociocultural contexts, collect the wisdom of the crowd to initiate different innovations through public–private collaboration, and encourage citizens to join in on the actions, which will lead to the formation of locally initiated innovative solutions such as the Repair Café, Urban Vegetable Garden, Community Renewable Energy Projects to converge and incorporate greater scientific research capacity.

B. Strengthen net zero living infrastructures through technological application and policy adaptation so that citizens can lead an affordable net zero lifestyle

(A) Reinforce environmental infrastructures that facilitate the promotion of net zero living, including by taking an inventory of bottlenecks that people and communities experience net zero, green living; establish low-carbon or energy-efficient building control standards; cultivate a sense of pride in building low-carbon communities, developing smart sustainable cities, and living with renewable energy.

(B) Strengthen net zero living infrastructures through technological application and policy adaptation to help citizens lead an affordable net zero lifestyle; for example, other countries have introduced personalized carbon footprint tracking or carbon neutrality apps such as Wren and Joro, whereas the Green Citizens' Action Alliance in Taiwan has introduced Scan-and-Buy app and ESG analyzer, with information transparency being the key.

(C) Use new technologies to build a smart green transportation network and infrastructure and develop policy evaluation tools to keep track of the effectiveness of carbon actions.

C. Develop a sound green industrial vocational skills training system to empower net zero talents and vulnerable populations

(A) Foster net zero talents by creating publicly accessible learning and skills training channels for populations whose jobs will be affected by the net zero transition.

(B) Aim to foster net zero talents in higher education by promoting the cultivation of civic wisdom through diverse learning and training channels and referencing the fully integrated training system adopted in Denmark to reinforce the connection between the university and vocational systems.

(C) Set up digital education, vocational training, and lifelong training platforms with reference to Google IT Certificates (IT Support Professional Certificate) and the Denmark government's Flexicurity mechanism; these platforms will have a vital role to play in business transformations during low-carbon transitioning.

D. Develop industries that specialize in green energy-related technologies to create green job opportunities

(A) Promote net zero emissions by 2050, strengthen the development of technologies and industries associated with offshore wind power, zero-carbon hydrogen fuel, green transportation, zero-carbon air/sea shipping, green building, and carbon capture and storage, and create more green job opportunities encompassing fields of green finance and innovation.

(B) Be proactive in adopting a pricing mechanism that guides energy and green industries to edge toward resource allocation and distribution in line with the cost-effectiveness of using the environment, thereby developing related industries to create job opportunities.

E. Develop distributed smart grids, encourage the installation of community-based renewable power plants, and promote diversification in energy production

(A) Develop regional distributed public facilities as the infrastructure for building a distributed, resilient social system that elevates the flexibility and resilience of the entire society to risks.

(B) Build distributed power grids and regional electricity deployment centers where distributed renewable energy is generated to facilitate wide-range distribution and build the resilience of electricity infrastructure.

(C) Actively promote technological applications to realize distributed energy production and power grids, make generating green electricity a responsibility of high electricity users, specifically by investing money in the development of facilities that facilitate the development and application of renewable electricity; shift centralized grids to distributed smart grids, which will strengthen the resilience of power supply systems and popularize smart meters in homes; encourage the installation of renewable power plants in communities so that more community-based people are empowered to participate in the installation of renewable energy, thereby fortifying a place’s link to renewable energy.

(D) Renewable electricity development must cross the boundary of users and producers so that communities and citizens become prosumers; one such example is the community renewable energy projects, which have fostered widespread civic participation by giving priority to local residents or through a platform built by the local government, and also encouraged stakeholders to jointly build a community-run renewable power plant by adopting innovative operational models in which they contribute professional skills and supply equipment.

F. Form a civic participation mechanism to promote local sustainable development and protect affected populations

(A) Encourage public–private collaboration on net zero technology to expand the spread of innovative applications so that net zero technologies can become socially acceptable.

(B) Engage in fiscal planning and develop relevant supporting measures that transfer resources to different regions, departments, and populations, including by building a provident fund feedback mechanism for NIMBY-opposed facilities or transferring the electricity generated from fishery and electricity symbiosis systems to local fishers.

(C) Strengthen environmental assessment by incorporating the direct and indirect impacts of carbon emissions and climate change.

(D) Develop a hierarchy-based net zero responsibility and resource distribution mechanism to facilitate strategic and fee planning for different targets and social classes (e.g., car drivers have a greater responsibility to undergo transformation than bike riders).

(E) Introduce user classification; for example, users of a renewable power plant are classified into industry users with high economic capability and SMEs and the public; policy tools are used to safeguard the rights of SMEs and the public to use renewable energy.

4.1.3 Interdisciplinary Talent Development, Labor Market Transformation, and Economic Equality

(1) Problems and Challenges

A. Increase in education gap and youth unemployment makes interdisciplinary talent development imperative

According to PISA 2018 results[20], over 17% of students in Taiwan failed to achieve basic learning skills, and performance in reading among the top 10% and bottom 10% of students showed approximately a 6-year learning gap. Compared to OECD countries, Taiwan's education

[20] F. Avvisati, A. Echazarra, P. Givord and M. Schwabe (2019). Programme For International Student Assessment, URL: https://www.oecd.org/pisa/publications/PISA2018_CN_TAP.pdf.

indicators still have room for improvement. The youth unemployment rate among young adults under 30 was considerably higher than that of working populations of other age groups, with the unemployment rate the highest (3 times as high) among those aged 20–24 years. The unemployment rate was 5.49% for young adults with bachelor’s degrees, which is 1.5 times higher than those with other education levels. These results show that Taiwan's education system and talent development strategies should be revised.

Digital technology's development has drastically altered global industries' structure, which drove up demands for new technologies and talents in new industries. According to the Manpower Supply and Demand Survey and Estimations for 2022–2024 published by the National Development Council[21], the pharmaceutical and biotechnology industry adopted multiple AI technologies in response to the COVID-19 pandemic and future care demands; as a result, demand for talent in the AI application service industry increased by 21.7%, which is higher compared to other industries. Furthermore, smart manufacturing is the focus of digital transformation and advanced manufacturing, which increased the demand for talent in the smart machinery industry by 11.9%. The growing demand for interdisciplinary and diverse talents will make it difficult to adjust policies and education systems in time. Fostering flexible adaptability and self-learning capability is critical to keep pace with the fast-changing international and industry trends.

B. Labor system needs to guide talent and industrial development to prepare them for the impact of and opportunities in socioeconomic transformation

In the midst of dual structural transformations (i.e., digitalization and net zero transition), the adoption and application of AI and other digital

[21]National Development Council (2012). Manpower Supply and Demand Survey and Estimations for 2022–2024, retrieved from: https://ws.ndc.gov.tw/Download.ashx?u=LzAwMS9hZG1pbmlzdHJhdG9yLzE4L3JlbGZpbGUvNjAzNy85NjIzLzI3ZmViN2I5LTdmZmUtNGQyYy1iNTU4LTUyY2NhNDFiMDM4OS5wZGY%3D&n=MTExLTExM%2BW5tOmHjem7nueUoualreS6uuaJjeS%2Bm%2BmcgOiqv%2BafpeWPiuaOqOS8sOW9meaVtOWgseWRiijlrprnqL8pLnBkZg%3D%3D&icon=..pdf.

technologies are more likely to replace repetitive jobs; however, S&T applications will also create new job opportunities. The key therefore lies in training or applying AI to help talents transition into high value-added jobs. Under industrial automation, the deployment of robotic process automation in industries mainly impacts middle-aged blue collar workers, as suggested by the 2021 Human Resources Survey Statistics[22], which reported 1.49 million blue collar workers aged 45–64 in Taiwan. It is therefore critical to help them undergo skills training and career transition in the future. With the gradual decline in working age populations, the government should help to increase the labor participation rate of middle-aged, elderly, and discouraged workers.

According to the Population Projections for R.O.C. (2020–2070) published by the National Development Council[23], the working-age population aged 15–64 years peaked at 17.37 million in 2015 and has since then been shrinking year after year. The working-age population is projected to be less than 50% of the total population by 2065, which will significantly affect the talent pool in Taiwan. The Working population comprises the workforce and non-workforce groups, the latter of which includes middle-aged people, people with physical/mental disabilities, women, new immigrants, indigenous people, and discouraged workers. The Directorate General of Budget, Accounting and Statistics reported in its Human Resources Survey Statistics[24] that the labor force participation rate of people over 50 in Taiwan was lower compared to other major countries in 2021, and this gap widened with age. Specifically, the rate for people between 50 and 54 years old was 75.4%, which is lower compared to South Korea (79.3%), Singapore (84.8%), Japan (87.5%), and the United States (79.2%). The rate for people between 55 and 54 years old fell to 58.9%. Discouraged workers are those who want to work but

[22]Directorate General of Budget, Accounting and Statistics, Executive Yuan (2022), Human Resources Survey Statistics Annual Report (2021), retrieved from: https://www.stat.gov.tw/News.aspx?n=4001&sms=11516.
[23]National Development Council (2022), Population Projections for the R.O.C. (2020–2070). Retrieved from: https://pop-proj.ndc.gov.tw/download.aspx?uid=70&pid=70.
[24]Ministry of Labor (2022), 2021 Workforce of Middle-Aged and Elderly People (>45 years-old), retrieved from https://www.mol.gov.tw/1607/2458/2476/lpsimplelist.

cannot find appropriate job opportunities and thus are not working. Discouraged workers with college degrees or above grew by 14% over the past five years, from 29,000 in 2017 to 33,000 in 2021[25]. The predicaments discouraged workers encounter when seeking jobs must be determined and addressed in order to direct them into the employment market to contribute their expertise, thereby preventing the looming loss of demographic dividend due to a reduction in the talent pool.

C. The working population is shrinking annually, which necessitates a systematic mechanism for recruiting international and overseas professionals, and also a friendly, inclusive social environment for talent retention

Statistics by the Directorate General of Budget, Accounting and Statistics and Ministry of Education showed that approximately 500,000 Taiwanese nationals were working overseas; 252,000 of them were aged 30–49 years working in major jobs, 390,000 had college degrees or higher, and 20,000 were studying abroad. In the face of the falling birth rate and shrinking working population, countries worldwide are enforcing talent recruitment policies, keeping track of and seeking graduates who specialize overseas in key fields, and providing competitive work environments such as the same salary standard as overseas, to attract international and overseas high-tech skilled workers.

(2) Response Strategies

A. Shorten the education gap by developing a relaxed education system, progressively opening up applications for school enrollment, and fostering highly adaptive and self-learning talents

(A) Develop student learning support systems for different primary and junior high schools in Taiwan, and use technologies to help underperforming students.

(B) Develop a course instruction mechanism in which students can

[25]Directorate General of Budget, Accounting and Statistics, Executive Yuan (2017), Human Resource Utilization Survey Report (2017), retrieved from: https://www.stat.gov.tw/News_Content.aspx?n=2798&s=88361.

personalize or tailor their learning to their personal situation and characteristics by using digital instructional materials on digital devices in a classroom, while teachers can provide assistance and guidance in the classroom according to the students' personalized/differentiated learning results; and provide after-school support by establishing a digital learning companion program that offers extracurricular learning support to diminish the education gap and enhance learning performance.

(C) Promote popularized digital learning through open educational resources, including fostering teams of seed talents to attend Massive Open Online Courses (MOOC), learn big data analysis capability, and develop professional course modules for Taiwanese society and industries and share them on Coursera edX platforms.

(D) Take progressive steps in creating an international knowledge/skills virtual academy that recognizes international professional remote learning programs and credit scores, progressively open up applications for school enrollment and digitally blended learning, and offer certified professional courses that are applicable throughout the life cycle to develop age-friendly self-learning environment and capabilities and cultivate professionals who are highly adaptable to challenges and changes.

B. Introduce business-sector resources to jointly assume the talent development responsibility, strengthen industry–academia cooperation and vocational training, promote a flexible and secure employment market system, and facilitate the bilateral development of talents and industries

(A) Encourage companies to join university programs and credit score certification systems, to establish courses in collaboration with universities, and provide a wide range of learning opportunities; adopt My Data mechanism and integrate it with learning programs, credit scores, and learning data platforms to help industries quickly find talents and to generate job performance reports, which can be used to adjust learning programs dynamically to meet talent development requirements.

(B) Allow companies to participate in vocational training and provide policy incentives that will advance the progress of training courses on digital technology; support the physical interactions of vocational training centers and increase the transparency of work contents and industry trends to help talented people transition into the employment market and unleash their skills.

(C) Introduce time bank or virtual currencies as incentives that encourage retirees to partake in teaching and adopt the non-profit model of Khan Academy to sustain the value of talented professionals and mitigate the impact of labor shortage.

(D) Learn from Denmark's Flexicurity Model, and provide employed and unemployed people with lifelong learning courses and certification mechanisms through a record of the learning process of the entire life cycle; provide (and encourage the industrial sector to do the same) customized employment transition measures for working populations that are affected by industrial transformation, including training them to obtain digital skills or certifications or introducing human–machine collaboration in the workplace, and offering open and diverse learning and skills training channels to help talents and industries continuously contribute their value as the world undergoes multifaceted just transition and gain growth opportunities.

(E) Incorporate unemployment benefits and active job-seeking requirements in re-training and employment arrangement policies, and through policy piloting, reduce legal restrictions on employment and dismissals, guide talents and industries to adapt to the fast-changing labor environment, and create an R&D/worker-friendly workplace environment that supports employees to apply their skills.

C. Establish a talent life cycle observation mechanism, improve the living and child-rearing environment in Taiwan, and perfect talent recruitment and retention mechanisms

Revise labor, economic, and technology laws and regulations, and establish a talent life cycle observation mechanism by integrating the talent pools of the Ministry of Foreign Affairs, Directorate General of Budget, Accounting and Statistics, Ministry of Education, Ministry of Labor, and National Development Council to provide channels for recruiting overseas Taiwanese talents, and offer remote work opportunities in collaboration with domestic enterprises to develop a sound talent retention and recruitment system for Taiwan, thereby creating a circulation of talents that runs both ways between Taiwan and foreign countries.

4.2 Interdisciplinary Frontier Scientific Research

The US–China tech rivalry has spurred other countries to become self-sufficient in the supply chain of sensitive industries, thus influencing the structural layout of industries in Taiwan. Taiwan needs to envisage its S&T development for 2035 and establish topic-screening criteria through interdisciplinary frontier scientific research to compete for a spot in the future development of emerging technologies.

With due consideration to national security and global challenges, Taiwan's strengths in S&T fields, national economic benefits, and promotion of social inclusion, this section will focus on four issues: Taiwan's independence in new-generation key technologies, satellite, and next-generation communication technologies, new energy technologies that are related to net-zero transition, and industrialized system for scientific research achievements. The problems and challenges of each issue and counterstrategies are described below.

4.2.1 Independence in New-Generation Key Technologies

(1) Next-generation semiconductors

A. Problems and Challenges

(A) Countries are committing to developing new-generation semiconductors, while Taiwan remains dependent on imports for critical materials and equipment; the challenge is maintaining Taiwan's leading role in developing semiconductors.

Geopolitical competitions around the world are intense. Countries such as the United States, China, Europe, Japan, and South Korea have invested in developing next-generation semiconductors. Advanced countries such as the United States, Japan, and Europe still need more control over the long-term development of crucial semiconductor materials and equipment. Taiwan must therefore maintain its world-leading position in semiconductor development; otherwise, the country's position in the global semiconductor industry will be affected. Regarding ways to equip materials and equipment manufacturing facilities in Taiwan to develop next-generation semiconductors, future economic benefits and industrial safety must be considered in preemptively planning to deploy frontier technologies and new materials.

(B) The challenge is redefining Taiwan’s next-generation semiconductor supply chains from the future application of industry systems

The challenge is redefining Taiwan's next-generation semiconductor supply chains from the future application of industrial systems. Taiwan boasts a world-leading semiconductor manufacturing industry; however, the sector still needs to be improved in next-generation semiconductor design, thus necessitating early deployment of electric vehicles, next-generation communication, and other new applications in demand. To continue improving the performance of electronic systems, particularly concerning power consumption and costs, the end of electronic system design will inevitably orient toward hardware–software co-design, and the heterogeneous integration of small semiconductor chips will likely dominate future development trends. However, this development direction will significantly increase the complexity and difficulty of verifying and structurally optimizing electronic system designs, in which case, co-design with car manufacturers or other relevant application fields is required to achieve the best outcome.[26]

[26]Yi-Hsin Wang (2022), ITRI Joins the Research and Development of Next-Generation AI SoC, retrieved from: https://wantrich.chinatimes.com/news/20221020900734-420501.

B. Response Strategies

(A) Cement existing advantages, integrate innovative resources through international cooperation, and co-create Taiwan's strengths in the development of next-generation semiconductors

Establish a world-class semiconductor development and value-added application center that equips materials and equipment manufacturing facilities in Taiwan to invest in the development of next-generation semiconductors and to focus on technological innovation; the center will be equivalent to a platform so that by strengthening Taiwan's capability to specialize in the development of autonomous technologies or key components and through strategic international cooperation on scientific research with reliable partners, major global manufacturers are driven to participate and invest in next-generation semiconductor development projects. With this world-class R&D center, Taiwan will be able to attract international professionals and increase its affinity to global equipment manufacturers in specific technology, materials, instrument, and equipment fields, which in turn strengthens the resilience of Taiwan's talent pool and elevates the autonomy and global impact of Taiwan.

(B) Redefine next-generation semiconductor supply chains as needed for the development of future new applications, and help the semiconductor industry in Taiwan to keep abreast of future market opportunities

a. Monitor the development characteristics of future new applications such as electric vehicles, next-generation communications, next-generation artificial intelligence, and high-speed computing; redefine next-generation semiconductor supply chains to align with industrial systems and specifications, and embed relevant value chains in the R&D stage to seize hold of the future application market.

b. Utilize manufacturing advantages to cooperate with the IC design industry, and encourage industry operators to monitor the characteristics of future applications and subsequently develop smarter, value-added modules and products that are characterized by high-speed computing, energy efficiency, real-time information process capability, and ultra-low latency.

(2) Precision Health

A. Problems and Challenges

(A) Integrating diverse stakeholders is urgently required to collectively build a business model that puts health-related data into practice

Health-related data are sensitive. These data are currently available for research purposes; however, the commercial application of these data will pose data governance challenges. Therefore, in developing the precision health industry, the perspectives of different stakeholders must be integrated throughout the process, from concept development to product launch. In addition, a friendly and secure data governance and data sharing mechanism must be established in conjunction with exploring a successful business model to develop a profit-sharing tool. A portion of the profits earned must be reserved as a social contribution to appeal to healthier communities and alleviate concerns about using health data, thereby creating a long-term development space and participation incentives for precision health development.

(B) The integration of ICT into health care is highly probable, but the environment and regulatory mix in relation to product development for precision medicine still have room for improvement

The current practice of using human genes and medical records as research data still needs to be optimized. To accelerate the integration and verification of precision health and AI and create a positive environment for the realization of precision medicine products, the government should establish a flexible, innovative testing mechanism, explore the scope of application in the government, healthcare, and industrial sectors, and speed up regulatory amendments to improve the data governance mechanism for the field of biomedicine.

B. Response Strategies

(A) Develop principles for healthcare data application to unlock the value of Taiwan's health-related big data

a. Develop principles for healthcare data applications, relax data usage restrictions to unlock data value, and develop more innovative applications.

b. Develop principles for using data, such as data legality (in obtaining patient's informed consent to the purpose of use), multiple mechanism principles (for profit in addition to for the benefits of the public), the right to withdraw (consent) at any time, and private security.

c. Establish data-sharing principles and operational mechanisms with reference to international guidelines (e.g., the FAIR Guiding Principles) to reduce data flow barriers.

d. Create precision health integration model for Taiwan on the premise that hospital operating systems are respected, and quickly establish a mechanism that ensures long-term effective use of necessary databases in Taiwan, such as using a federated learning approach to overcome restrictions on the use and integration of highly sensitive private data.

(B) Establish demonstration cases through pilot projects to create a new future of people-centered digital health

a. Establish demonstration cases by referring to U.S. data-sharing platforms and implementing pilot projects, to demonstrate both the security and benefits of sharing data and thus boost public confidence in open data.

b. Develop test database and cloud-based platform that is open to researchers through pilot projects on disease data specific to Taiwanese nationals, demonstrate the transparency and interoperability of data, and uncover the value of data while ensuring patient data security.

c. Facilitate the process of integrating data into medical treatment and health care so that it spearheads the transformation of existing healthcare systems and service models, helps identify affordable costs and provides, and provide more valuable, effective, and high-quality care solutions to create a new future of people-centered digital health.

(3) Quantum Technology

A. Problems and Challenges

(A) Globally, there are still uncertainties in the pathway to the development of quantum technology, Taiwan needs to carefully choose which key technology fields to specialize in

Globally, there still are uncertainties in the pathway to the development of quantum technology. International corporations (e.g., IBM) opted for superconducting quantum components. However, silicon-based quantum and light quantum components are equally promising in terms of breakthrough development. Which quantum components will be mainstream in core computing remains unknown, Taiwan needs to understand the key technologies used to develop the different components, and choose wisely which key technology fields it should specialize in.

(B) Taiwan lacks the talent pool to develop quantum technology, it needs to cultivate experts in the field and attract foreign professionals

The world, including Taiwan, has a lack of talent in the field of quantum technology. Taiwan needs to cultivate experts in the field and attract foreign skilled professionals. However, quantum technologies are viewed by many countries as a sensitive technology, so Taiwan must have strengths in relevant fields in order to attract world-class quantum technology experts to impart their experiences and bolster Taiwan's R&D capability.

(C) Taiwan should provide incentives that entice domestic industries, international corporations, academic sector, and research communities to collaboratively develop core components and key equipment

The world is ramping up investments in quantum technology. International corporations are building their own global R&D network in quantum technology to bolster their R&D capability and strive for leadership in quantum computing. For example, IBM and Yonsei University collaborated on bringing together industry, academic, and research institutions in South Korea to build a local ecosystem that advances quantum computing and grows the pool of quantum talent[27] so that South Korea becomes the fourth country in the world to have an on-premises IBM Quantum System One after the United States, Germany, and Japan. The key problem with quantum computers and quantum communication is that materials and processes must be precise to control quantum state. With limited resources, Taiwan needs to promote joint R&D efforts across domestic industries, international corporations, academic sector, and research communities, in order to accelerate technology development and industrial applications, develop core components and key equipment, and ultimately become a key quantum technology player in the world.

B. Response Strategies

(A) Choose the most beneficial key components and key nodes as point of entry into the international quantum computer industry chain

Take advantage of Taiwan's strengths in controlling the IC and high-end semiconductor manufacturing industry and technologies and accelerate investment in the development of ultra-cold quantum sub-system ICs to penetrate the international chain of quantum computer industries.

(B) Develop quantum computer components and peripheral key equipment to attract world-class quantum talents

[27]IBM and Yonsei University Unveil Collaboration to Bring IBM Quantum System One to Korea (2022), retrieved from https://www.fromgeek.com/telecom/450926.html.

a. Promote Taiwan's development characteristics in the quantum field to build collaborations with world-leading talents and strengthen the country's R&D capabilities.

b. Promote joint R&D efforts in quantum computer components and peripheral key equipment across domestic industry, academic, and research institutions by drawing on the foundation of the electronic OEM industry to demonstrate Taiwan's research capability, which in turn attracts R&D and experimentation collaborations with world-class talents.

(C) Forge strategic partnership with world-leading companies to build Taiwan's capability in quantum communication or quantum computer systems

Niche the foundation of Taiwan's semiconductor industry and its expertise in management, materials, testing, or infrastructure, leverage existing resources, actively cooperate with world-leading manufacturers in Taiwan-friendly countries, develop system prototypes, and build Taiwan's system capability.

4.2.2 Satellite and Next-generation Communication Technologies

(1) Problems and Challenges

The ecosystem of satellite and next-generation communication industries is composed of two parts, namely manufacturing and services (Figure 4-1). Manufacturing includes part manufacturing, subsystem manufacturing, satellite manufacturing/system integration, and ground station manufacturing. Services include satellite operation, launching of rockets, and value-added services.

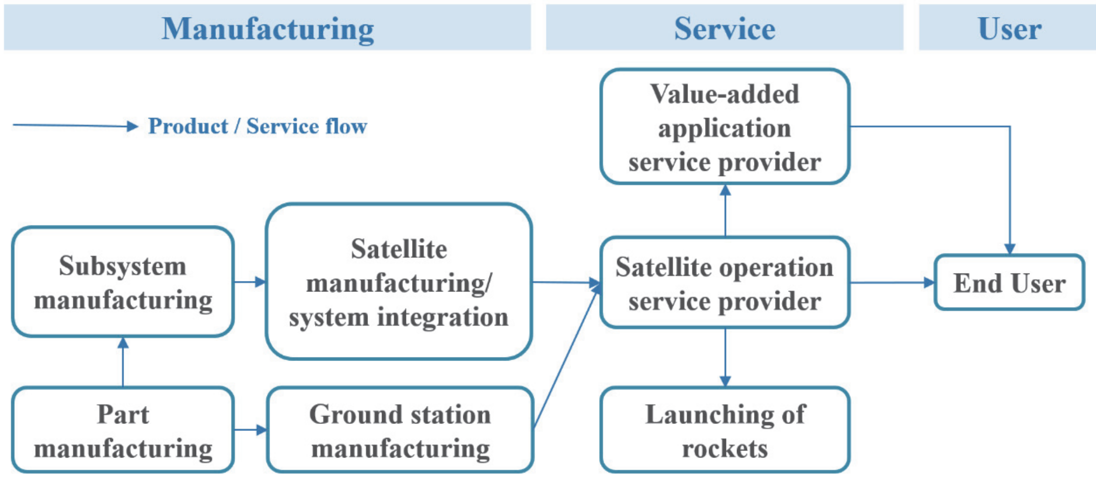

Figure 4-1. Ecosystem of satellite and next-generation communication industry
Data source: ITRI Industrial Economics and Knowledge Center.

Taiwan has been committed to enforcing policies relevant to satellite and next-generation communications; however, the country still encountered the following problems and challenges:

A. Development at technology level is focused on parts, while core technologies are still being developed in-house

Taiwanese manufacturers are committed to manufacturing aspects and have deployed end products such as frontend modules or parts, satellite set-top boxes, and navigation systems, across international markets. However, core receiver technologies required for low-earth orbit (LEO) satellite ground stations are still being developed in-house, and no commercial-use products have been launched yet.

B. Manufacturers lack system integration capability and depend on foreign-based rocket launches to test self-developed satellites and parts

Satellite manufacturers in Taiwan are mostly small and medium-sized enterprises that lack system integration capability. There are no world-leading companies in Taiwan that specialize in system integration and software development. Observing the development of satellite and next-generation communication development reveals that future applications will encompass metaverse, industrial automation, and self-driving cars, making system integration more complicated. The world has been advancing toward network deployment, and Taiwan should step up its efforts in this aspect.

Taiwanese vendors are not yet actively involved in providing relevant services. In the field of rocket launching, Taiwan currently lacks the capability to launch large rockets, self-developed satellites and parts must be sent overseas for rocket launch tests, the country typically acts passively as it has no power and control over timing in terms of developing and testing satellites and associated parts. Satellite parts and systems must be subject to rigorous aerospace testing to ascertain their ability to withstand intense vibration during a rocket launch, radiation and high temperature difference in outer space. Although some of these tests can be done in laboratories, on-site testing would increase reliability. For this reason, Taiwan needs a rocket launch testing site so that Taiwanese manufacturers of satellite parts can test their products onsite in Taiwan to shorten development schedule and cut costs.

C. Industries are reluctant to invest in the satellite field, limiting the pool of talents in the field

The key to strengthening Taiwan's capability to build an ecosystem of satellite and next-generation communication industries includes accelerating the development of relevant core technologies, filling the industry gap (e.g., rocket launching), introducing more incentives that encourage private involvement, and fostering talents in the field. In Taiwan, satellite development and manufacturing are overseen by Taiwan Space Agency and universities, with minimal involvement from the private sector. For instance, the outer space has a harsh environment, so chips for space devices must work normally in a highly radioactive environment. To achieve this, space-grade ICs are designed to be radiation-hardened. However, because radiation-hardened ICs are produced in low volume and high variety, industry input is currently limited, coupled with limited university staffing and budgeting, a talent gap in the field of satellite and next-generation communications still exists between Taiwan and other countries.

D. An effective dual-use (military and civilian applications) scientific research result exchange mechanism is lacking

Satellite and next-generation communications are dual-use technology, particularly in the field of rocket launching. Military research institutions have built strong research capabilities and a wealth of research results, which are only available for military use. There is no mechanism or channel for military and civilian exchange, so the results cannot be put to good use in the private sector to advance technological development in the field of satellite and next-generation communications.

(2) Response Strategies

A. Bolster Taiwan's advantages in core satellite technologies by establishing the complete stage of development from CubeSat, microsatellites, and low-orbit experimental satellites to low-orbit galaxies

Scale up the development of Taiwan's satellite industry by aiming for the complete stage of satellite development from CubeSat, microsatellites, low-orbit experimental satellites to low-orbit galaxies to expand the early application of space components in Taiwan.

B. Build capabilities to mass produce and optimize the systems of satellites, rockets, next-generation communication technologies, and encourage leading companies to provide systematic solutions and establish their global presence

(A) Develop a national-level public–private collaboration innovation platform, take into consideration the development needs of Taiwan and other countries and the technological capability of industry, academic, and research institutions in Taiwan, and build a complete ecosystem comprising satellites, ground stations, rockets, and relevant services through long-term flagship projects, develop core satellite and next-generation communication technologies that are suitable for Taiwan, and support industries to build mass production and system integration capabilities.

(B) Help benchmark satellite manufacturers through large satellite system development projects to become system integrators instead of part suppliers, and build Taiwan's capability to mass produce and optimize the systems of satellites, rockets, and next-generation communication technologies so that benchmark vendors in Taiwan are capable of providing metaverse, industrial automation, and self-driving car solutions to establish a global presence.

C. Enhance Taiwan's space industry development capacity by devising long-term satellite communications/next-generation communication industry capability and talent pool building plans

(A) Enrich scientific research capability and foster satellite and next-generation communication scientific researchers by taking advantage of large-scale galaxy projects, academic and research training, and world-class talents, and raise young scholars' awareness of satellite and space science and help improve their skills to expand Taiwan's talent pool for the development of satellite and next-generation communication fields.

(B) Transfer corporate, academic, and research ownership of satellite technologies to major companies, and strengthen the testing of parts in a space environment and meanwhile, organize large flagship projects to collaborate with the private sector on rocket development, and provide fiscal funding to encourage the development of startup companies in the field of space science.

(C) Expand the organization of Taiwan Space Agency's Space Academy so that industry practitioners can continue their education while on the job and gain real-life experiences in system integration, and encourage universities to set up space-related undergraduate and graduate programs to cultivate grassroots and high-caliber professionals.

D. Develop a bidirectional (military to civilian and civilian to military)

technological cooperation mechanism that facilitates military and civilian use of research resources to accelerate relevant technological development

Strengthen the connection between private technologies and military technologies, build a national defense military technology collaboration platform, encourage national defense scientific research institutions to enter a technology licensing agreement with academic and scientific research institutions or companies, and adopt the approaches of the U.S. Defense Advanced Research Projects Agency to set up the TOOLBOX initiative, which acts as a platform for formulating standard legal provision and procurement/technology transfer procedures to streamline negotiations and technology licensing agreements between military research institutions and the private sector.

4.2.3 New Energy Technologies that are Related to Net-zero Transition

(1) Problems and Challenges

A. Countries are investing in new energy research, Taiwan needs to find a new high ground over mid/long-term development of energy technologies, but its S&T resources are limited

Key emerging energy technologies for reducing carbon footprint in the future are still at the nascent or demonstration stage of development. While countries worldwide are committed to new energy studies, Taiwan needs to find a new high ground over the mid/long-term development of energy technologies; however, Taiwan has limited scientific research resources. It is therefore imperative to select the energy that is suitable for the geographical development of Taiwan and consolidate industry, academic and research resources; otherwise, the industry competitiveness of Taiwan will be affected.

Although budgets have been set aside for net zero transition, the ministries must apply for it themselves. Aside from the fact that the applications might overlap, creating a systematic upstream and downstream link is also difficult, causing long-term technology deployment plans to be implemented in fragments during ministry-level projects, which makes it difficult to integrate the performance of each ministry.

B. Incentives must be introduced for new energy development and public communication should be strengthened to reduce development resistance

New technologies must be deployed with creating new markets in mind, but developing new markets is challenging. Developing new technologies to putting it into practice is a long-term process; for example, grid deployment problems will emerge as the scale of renewable energy expands in the future, at which point developing energy storage and battery systems will be key solutions. However, industries are unwilling to invest in these solutions because investments take time and cost competition with other countries is stressful. Design mechanisms are required to drive industrial input so that industries may exploit their R&D capability.

In addition, necessary support and adaptation solutions to the social impact of new energy technology R&D and experimentations, must be put in place to alleviate public concerns about new technologies, thereby successfully realizing net zero transition. Therefore, new technology development necessitates not only speeding up technical input and also strengthening communications with public to educate people as soon as possible and establish low carbon awareness and lifestyle to create an environment that facilitates industrial development.

(2) Response Strategies

A. Integrate net zero budget resources, speed up the development of new energy technology that fits the environmental characteristics of Taiwan

Integrate net zero budget resources through multi-year yuan-level S&T plans to shift away from the past ministerial competition model, and establish a coordinating unit that oversees resource plans and usage, propose specific research directions and division of labor, integrate the research capability of institutions that are affiliated with each ministry, develop new energy technology that fits the environmental characteristics of Taiwan, and accelerate the process of industrialization.

B. Strengthen incentives that motivate industry participation and expand communication with the public to successfully realize local testing of new energy technology

(A) Set up industry voluntary emission reduction incentive mechanism, pursuant to the amended Climate Change Response Act, where the mechanism uses carbon fees and funds as incentives; adopt the Statute for Industrial Innovation, subsidize R&D on emission reduction, and guide industry input into R&D on net zero technologies.

(B) Engage in dialog and communicate with the general public to obtain their consensus and support, which is conducive to building sites for testing new energy technologies such as hydrogen.

4.2.4 Industrialized System for Scientific Research Achievements

(1) Problems and Challenges

A. The government has launched the business angel investment program, but private investments remain inadequate

Government resources, industrial sectors, and capital markets all have a vital role to play in S&T development. The Taiwanese government has launched a business angel investment program, which slightly improved early-stage investments. However, in general, private investments were still inadequate, with the scale of early-stage investments not on par with the world standard. Investments in global startups were mainly derived from early-stage deals (including Seed/Angel to Series A), which accounted for 60% of total investments. Median funding raised increased from US$1.1 million in 2015 to US$2.6 million in 2021[28]. By contrast, based on the number of transactions, Taiwanese startups raised at most less than US$1 million between 2015 and 2021, which is lower than the US$2.6 million early-stage funding

[28]CB insight. (2021). State of Venture: Global data and analysis on dealmaking, funding, and exits by private market companies. Retrieved from https://www.cbinsights.com/reports/CB-Insights_Venture-Report-2021.pdf.

raised globally, suggesting that early-stage investments in Taiwan must be strengthened.[29]

B. There are limited growth opportunities for domestic markets, international ties and investment capability must be strengthened

There are limited growth opportunities for domestic markets. S&T startups need to step up investments in international markets; however, Taiwan lacks management talent. The government must, therefore, help startup companies forge international ties, such as by creating opportunities for startup teams to participate in foreign accelerators, recruit international talents, and accelerate global expansion. Access to international funds and ties for startups needs to be strengthened concurrently. However, current laws and regulations pose restrictions on administrative procedures to avoid profiting from foreign funds and avoid the risk of investments from mainland China. For instance, international venture capital investment in Taiwanese companies needs to be reviewed by the investment review committee, which will lengthen administrative works by 1 to 3 months. It is therefore necessary to amend relevant legal restrictions and actively encourage international funds to invest in Taiwan.

C. Increasingly complex social needs necessitate interdisciplinary collaboration in order to effectively tackle social challenges

Increasingly complex social needs require interdisciplinary collaboration among public and private sectors in key areas in order to effectively tackle social challenges. However, it is difficult to promote problem-oriented research for many urgent or unmet social needs, because technical solutions are not yet ready, academic and research institutions are unwilling to invest, and better incentives are needed for cross-ministerial S&T cooperation projects.

(2) Response Strategies

A. Provide better investment conditions that attract early-stage funding

[29]Taiwan Institute of Economic Research, 2022 Early-Stage Investments in Taiwan: General Overview. Retrieved from https://findit.org.tw/researchPageV2.aspx?pageId=2117.

for Taiwan from domestic and foreign venture capitals

(A) Accelerate link between domestic and foreign venture capitals, exploit their funds, talent pool, international market development and other experiences to support venture development in Taiwan, provide capital investment as encouragement to attract domestic and international venture capitals and participate in early-stage fundraising for new ventures in Taiwan.

(B) For example, attract international venture capitals and seek their commitment to set up a base in Taiwan and to help Taiwanese startups forge ties with overseas markets; meanwhile, prompt the Taiwan government to invest in a certain ratio or amount of shares in international venture capitals or to subsidize a portion or a certain amount of funds raised for Taiwanese startups from domestic or international venture capital firms.

B. Subsidize expenditures on R&D carried out by Taiwanese startups in collaboration with transnational companies, and connect to their experience to speed up the internalization of Taiwanese startups

Encourage cooperative projects among transnational companies and startups to attract cooperation between transnational companies and startups or research institutions; for example, if a transnational company were to engage in cooperation on R&D with a Taiwanese startup to cultivate the international market and promise equity investment in the startup for at least 5 years, then the government could subsidize a portion or a certain amount of expenditure on R&D or grant a portion or a certain amount of operating fund every year, and provide professional or institutional related technical resources.

C. Propose themed projects that are focused on the S&T development of Taiwan to encourage team building among industry, academic, and research institutions to establish consensus on R&D

(A) Allocate S&T budgets for unmet social needs and key technology R&D.

(B) Build a mechanism for engaging in cross-ministerial dialog on different needs to collect ideas from the public on the application of technology to solve societal problems, including declining birth rate, population aging, self-sufficiency in resources and energy, and large-scale disaster response.

(C) Allocate S&T project funding in which social benefits outweighs economic benefits, provide target achievement rewards to encourage industry input, and adopt civic participation mechanism to address major societal concerns.

4.3 Resilient Innovation Economy

The global political and economic environment is changing fast, causing the restructuring of global supply chains, which affects the future industrial development of Taiwan. Therefore, making Taiwanese industries more resilient and improving their economic innovation capability is important for future industrial development. Global supply chains are transforming into local short-chain supplies, which are changing the way future industries collaborate and bringing global changes and transformations to vendors. Industrial development and innovation and the need for social inclusion and local urban/rural development are changing science park functions and operations. The digital economy is entering a new stage of development, the rise of data economy and trustworthy technology became the foundation for virtual economy development. The global demand for emissions reduction due to reinforced greenhouse gas emissions control is driving industrial S&T innovation toward a new direction, providing new pathways for the development of new technology industries.

Looking ahead of the socioeconomic outlook of Taiwan in 2050, deepening international exchanges, strengthening the synergy of cross-border cooperation, accelerating the upgrading of industrial parks and the development of emerging technologies, and transforming industries to achieve digital and green economy, are issues critical to the economic development of Taiwan. Therefore, the economic aspect is focused on key issues of the future, including how to build resilient supply chains; accelerate the transformation of science parks; create an environment conducive to digital economy development; and the needs of industries in response to a green economy. Measures such as technology application, talent cultivation, and regulatory amendments are taken to promote frontier technologies as key solutions for industries to strengthen the economic competitiveness of Taiwan. The four issues, including problems and challenges, and counterstrategies, are detailed below.

4.3.1 Resilient Supply Chains and Economic Security

(1) Problems and Challenges

A. Policy and regulatory factors impede innovation and obstruct industry resilience

The resilience of supply chains and collaborative relationship between industries and countries are affected by the way different ministries coordinate their policies. For example, although the Ministry of Economic Affairs is in charge of the manufacturing sector, industrial innovation and ecosystem development are supported by the resources and policies of S&T and education sectors. Therefore, how to integrate and extend innovation results through industry ecosystems, thereby strengthening industry supply chains, is the future challenge of S&T policies.

In the service sector, ministerial communication and coordination affect the resilience of industry supply chains. For instance, health professionals in the medical service sector typically provide consultation and prescription services in person; however, during the COVID-19 pandemic, the rise of technological innovation made telemedicine and drone medicine delivery possible. If the pandemic had not overloaded the health care system, forcing competent authorities to allow remote consultation and medicine delivery services, Taiwan would still be grappling with using technological innovation to strengthen industrial resilience.

Supply chains in Taiwan can be roughly divided into suppliers of strategic stockpiles for domestic demand, suppliers of high-tech industries (these suppliers possess distinctive competencies), and general suppliers that engage in mainly traditional manufacturing activities. Each of these suppliers has their own operating mechanism that requires different policies and technologies to strengthen their resilience in sustainability. How the legal system in Taiwan can help various industrial systems improve their resilience has also become a key issue for future industrial development.

B. Socioenvironmental factors affect supply chain resilience

Supply chain resilience is tied to the stability of the social environment and also the stability of employment market operations, workforce quality, and costs. Due to net zero emission requirements, industries will be obliged to increase the use of renewable energy and reduce production carbon footprint, all of which affect supply chain resilience. Building a social environment that is conducive to industrial development, is also key to bolstering supply chain resilience. In addition, an industrial development model characterized by stable workforce supply and overall friendly social environment is key to sustaining the resilience of supply chains. Creating favorable cooperation mechanism for Taiwan and strengthening the resilience of industry supply chains and the society are important topics for the development of Taiwan.

C. Lack of new technologies as technical support makes it difficult for industries to improve their supply chain resilience

New technologies help Taiwan strengthen its supply chain resilience. For example, 3D printing using new materials will give rise to a new mode of production operation, in which short supply chains will supply the demands of the global consumer market and change the way globalization is structured and finished products are produced, becoming a new supply chain model. Frequent application of 3D printing involves the use of new materials, digital twin, and new printing equipment among other scientific research results. Without basic technologies, industries will face difficulties in using 3D printing technologies to develop more resilient supply chains. Adopting new technologies is challenging for industries because of hardware incompatibility or difficulty in replacing old equipment. Consequently, industries cannot keep up with new developments, which in turn challenge the resilience of their supply chain. When a new technology is in its early-stage development, problems such as immature technology and high cost deter business investments in new technologies to replace obsolete technologies. In light of this phenomenon, the resilience of industry supply chains can be strengthened by urging industries to adopt new technologies to prepare for a future of new business models, avoid the impact of paradigm shift, and reduce the operational impact of the new business model.

D. Industries are not adequately protected from political and economic risks, which shows that industry autonomy has room for improvement

Apart from TSMC, Taiwan has numerous other world-leading industries; however, whether these industries, in face of global competition and future changes in supply chain structures, can continue to maintain their competitiveness and safeguard Taiwan's economy is a key issue that must be discussed in the future. Therefore, the future of industries should be one in which Taiwanese-based companies hold control over main industry clusters, instead of focusing their development on manufacturing, with foreign investments in mergers and acquisitions becoming a key tool for industry expansion. The ability of industries to tackle future risks affects the economic security of Taiwan. In terms of S&T planning, except for the semiconductor industry, Taiwan has not yet planned Key Enabling Technologies like Europe did to protect the technology autonomy of its industries. This shortcoming may put the economic security of Taiwan at risk of having insufficient investment in next-generation technologies.

E. Food security affects economic development and security

Food security is a major food challenge on a global scale mainly because the global population is still growing, but agricultural lands have shrunk sharply, the agricultural population of main countries is aging rapidly, and challenges from climate change have emerged. Geopolitical conflicts will also indirectly affect food supply and security. Food security issues include the medium- and long-term depletion of marine resources and transitioning from fishing to farming is also a research direction pursued in various countries. Changing farming and fishing practices involves the integration of multiple technology fields and investment willingness of the business sector. Improving the consumption of key resources (fresh water, energy) during the agricultural production process and the possibility of increasing protein sources are all key to ensuring food security in the future. In 2021, Taiwan reported a food self-sufficiency rate of 31.27%[30], relying majorly on imports, primarily because staple food is not the main product of agricultural production in Taiwan and that local production costs are too high to compete with imported products. Relevant policies are also not helpful in achieving expected targets. Therefore, Taiwan must improve its food self-sufficiency rate in order to prepare for any potential international food price crises and safeguard the economic development and security of Taiwan.

(2) Response Strategies

A. Use a technology-oriented innovative regulatory sandbox mechanism and draft plans for integration with and invest in innovative technologies and industries

(A) Utilize a supervisory sandbox mechanism to promote innovative technology as an element of industrial resilience, speed up market adoption and development of such technology during the promotion of S&T innovation and application, while ramping up investments in strategic technologies to prepare for future technological competitions and industrial resilience.

(B) Diversify the operation of this sandbox supervision mechanism so that it can align with different S&T development characteristics and address needs for industrial resilience—for example, a regulatory

[30]Council of Agriculture, Executive Yuan. Agricultural Statistical Data Inquiry, retrieved from https://agrstat.coa.gov.tw/sdweb/public/indicator/Indicator.aspx.

sandbox for energy technologies involves a number of software/hardware components and users, so providing an operating interface link is necessary and critical; existing regulatory sandboxes are mainly used to test and verify sites, their functions will be extended to test concept technologies and business models, functions similar to these are found in financial regulatory sandbox and regulatory sandbox for self-driving cars.

B. Utilize innovative technology to create industry-friendly environment and risk assessment, and provide more assistance to industries through cross-ministerial coordination and integration

(A) Strengthen workforce supply in industries, increase labor force participation rate in Taiwan, and build a friendlier workplace environment.

(B) Provide a wider range of job opportunities and workplace-friendly environment through innovative technologies.

(C) Adopt assistance programs that are currently available to the business sector to facilitate the stable growth of this sector to mitigate the impact of industry uncertainties, thereby strengthening the overall resilience of industries; and help vendors conduct supplier risk and early warning assessments, leverage the strengths of Taiwan to fortify collaboration with the industry supply chains of other countries, reduce the impact of risks faced by industries in Taiwan, and ultimately create a friendly and resilient environment for industrial development.

(D) Consolidate central and local resources through cross-ministerial coordination to bolster supply chain resilience and, with minimal resources, develop a powerful industrial structure that features resilient supply chains.

(E) Establish a transnational geopolitical risk data assessment database, track changes in the supply and demand of raw materials and components in various key industries, and conduct real-time supply chain risk assessment and recommendations.

(F) Establish smart key infrastructures, and strengthen the technological capability of domestic industries to independently produce key materials, build a recycling and reuse system that drives a circular economy, reduce our dependence on global supply of key raw materials, and enhance the resilience of supply chains in Taiwan to develop autonomously.

(G) Promote the integration of technology-based services into international tourism to boost local retail service industries, and create online experiences that demonstrate the unique characteristics of tourist attractions in Taiwan to attract and entice international tourists to visit and experience Taiwan on-site.

(H) Improve the ability of local retailers and tourism service providers to use digital technology to keep abreast of tourist behaviors, and to adopt technology to provide smart translation and virtual tour guide services, which will help them strengthen their shopping tourism strategy, improve the quality of online and offline services, and increase return tourist shoppers, all the while taking Taiwan's international tourism to a whole new level.

C. Fortify link that connects industrial resilience to S&T and R&D results

(A) Capitalize on existing S&T innovation and entrepreneurship plans to strengthen the capability of scientific research systems to solve problems for enterprises; mitigate significant negative impacts on supply chain operations, such as changes in supply chain structure, pressure from global net zero transition, and geopolitical risks, to transform Taiwan into the most resilient industry structure in the world.

(B) In addition to original research works, develop a scientific research system that also assists industries with pilot mass production, enables industrial sectors to engage in concept or small-batch production, verifies whether a concept is feasible, and helps develop relative manufacturing capability and technologies, so that when industries have to adjust their resilience for sustainability, their innovation and

R&D activities will be supported by the scientific research system, they can also use small equipment or mass production facilities to prepare for mass production works and reduce risks that may arise from large-scale investments.

(C) Help SMEs adopt digital twins in smart physical and virtual factories by establishing digital platforms, among other measures that will help companies quickly learn and achieve smart business prediction and decision-making, real-time remote collaboration, uninterrupted operation worldwide, and fully-linked production and global supply chain scheduling, all of which contribute to the realization of a new smart manufacturing model for lights-out factories around the world, encourage high-end manufacturing, assist with industry upgrade, and enhance international competitiveness.

D. Set up a key industry protection mechanism and develop a cluster of sacred mountains that protect the nation's key technology industries

Integrate the existing capabilities of the semiconductor industry into food, clothing, hospitality, travel, education, and entertainment industries, and implement a mechanism for the semiconductor industry to cooperate with other new industries, develop an industrial cluster consisting of smart agriculture, precision health, metaverse, smart electric vehicles, next-generation communications, and smart manufacturing, accelerate the vertical integration of semiconductors and application industries, and tap into the strengths and capacity of the semiconductor industry to accelerate the development of new industries.

Develop a sacred mountain strategy for forming a cluster of Mittelstand industries that will safeguard Taiwan: (1) In terms of technology planning and resource distribution, strengthen the operation and control of scientific research systems, keep track of S&T budgeted projects and results, establish an objective evaluation mechanism, make plans for how the budget will be used and distributed, and ensure adequate funding for long-term planning of cross-ministerial scientific research projects that feature strategic value. (2) In terms of market and industrial development risks, build a data integration mechanism, and regularly assess the risks of industries that are subject to malicious dumping and restriction of sales by specific countries. (3) In terms of national human resources, consolidate immigration and industrial policies to ensure the availability of human capitals for industrial and economic development. (4) In maintaining societal resilience and international ties, develop a second international communication network, using backup communication network systems that feature asynchronous communication satellite and optical cable technology, strengthen our ability to identify and defend against cyberattacks, maintain the quality of communication and mobilization capabilities among various societal sectors, and promote cooperative innovation among strategic industries in Taiwan to form a crucial basis for emerging S&T industries in the future.

E. Promote the industrialization and smart integration of agricultural production to increase food self-sufficiency, and build a sustainable ecological environment

(A) Improve Taiwan's ability to produce and import non-rice crops and develop innovative sources of protein production.

(B) Promote agricultural automation and smart integration, accelerate industry adoption of smart agriculture knowledge and technologies by urging industry cooperation and guidance, promote partnership between "farmers" and "agricultural companies", and industrialization to reduce risks in agricultural operations, thereby improving overall agricultural productivity and capacity.

(C) Develop food and protein production technologies that are aligned with Taiwan's environmental conditions, and establish an environment in Taiwan where food self-sufficiency and food security are ensured to prevent food shortages in the future.

(D) Ramp up investments in marine technology and resource development, designate 30% of Earth's land and ocean area as protected areas by 2030 in the spirit of the 30 by 30 initiative, build a sustainable ecological environment, and explore the ocean surrounding environment for the future to establish a marine strategic development roadmap and achieve sustainable development goals.

4.3.2 Development and the Transformation of New Technology Industries

(1) Problems and Challenges

A. The paths taken by new technology industries around the world will affect the allocation of resources to science and industrial parks

Based on the economic structure and industrial development of Taiwan, international development and cooperation is necessary for all industries in Taiwan. Therefore, the transformation of science parks must be based on the socioeconomic outlook of Taiwan in 2050 and combine the blueprints that other foreign countries have developed for their vision of the future, in order to plan development strategies for next-generation industries in Taiwan. Affected by the medium to long-term industrial transformation strategies of various countries, the future of industrial development will take a different path. For example, the metaverse has been viewed as a highly promising technology. If Taiwan intends to develop the metaverse industry in line with global trends, the country will need to contemplate its strengths, weaknesses, and development environment in relevant fields, and exploit science park resources in order to attract startup businesses, develop technologies and services for international markets, and emerge as a provider of content services and applications instead of software/hardware integrator.

B. The demand of new technology industries is outpacing available talent

To facilitate the development strategies for next-generation technology industries, Taiwan needs to build an industry-friendly environment in the future for the incubation of next-generation technology industries. Intermediate and highly skilled workers will affect the development of next-generation technology industries in Taiwan. Therefore, fostering talents with expertise in new technologies and providing an environment that is conducive to the circulation of international talents, are problems that must be addressed in transforming and upgrading science parks. In addition, a *Micasa Sucasa* talent recruitment program for a physically and virtually integrated industrial environment is also key to attracting highly skilled foreign workers.

Training typically requires time. Past approaches to satisfy future manpower demand of industries include taking an inventory of the human resources needed by industries, adjusting higher education systems, and providing on-the-job training or career transition training mechanisms. A policy-governed training model is easily affected by temporal factors, causing supply–demand imbalance in the employment market, which also crowds out resources for training highly skilled workers. For this reason, the mechanisms by which existing science parks train and supply highly skilled workers will affect the transformation of science parks. The mechanisms by which science parks consolidate local educational resources for manpower training to supply additional sources of highly skilled workers for industries will also challenge the science parks' governance capability.

C. Business operators in Taiwan are challenged by global competition in new technology industries

From an industrial development perspective, new technology industries possess the attributes of a global market. In other worlds, these industries have always been competing with other industries on an international scale. The protective and business nature of local markets are of limited benefit to business players in the global market, particularly in the development of emerging digital technology markets. Potential obstacles that Taiwan may face in the development of new technology industries include finding ways to strengthen the ability of operators of new technology industries in Taiwan to operate on a global scale, and helping them advance into the global market with Taiwan as their stepping stone. From a global perspective, these problems also include determining how to operate the market and how international talent flow and capital can help new technology industries to develop rapidly.

D. Strengthen the role of industrial parks as an innovation hub to spearhead industry upgrade and transformation

Taiwan boasts three major science parks, which are a cluster of high-tech industries formed under the global division of professional labor. Science park systems and policies are conducive to Taiwan's economy and employment market. In face of global challenges such as climate change, geopolitics, digital revolution, and COVID-19, next-generation science parks must strengthen their role as an innovation hub to accelerate social changes that are driven by innovation across industries. Examples of these changes include promoting innovation communities and strengthening partnerships between large corporations and startups. Industrial parks in Taiwan were previously considered a display window that showcases the science and technologies of Taiwan. In the future, they should be integrated with the functions of an innovation hub, becoming not only the central prototype of industrial parks in Taiwan but also a pluralistic breeding ground for innovative services and creative technologies. The capability to integrate local and global demands and quickly incubate innovative enterprises is the key for industrial parks in Taiwan to emerge victorious in face of new modes of global competition. In the future, the Taiwan government should think about how to exploit park infrastructures and guide innovation and R&D capabilities, thereby becoming a key driver of regional innovation, net zero transition, and digital transformation.

E. Current science parks should strengthen, deepen, and broaden their regional ties, and strive to participate in local smart integration

Determining ways to translate scientific research results of public and private research institutions into industrial applications so as to facilitate industrial innovation and production, has been a topic of interest in the current knowledge economy era. How information is circulated, the interaction between people, systems, and geographical boundaries are all factors considered during this process[31]. Clustering of industries has a vital role to play in technology transfer and innovation. Regional clustering facilitates the innovation of new companies, while the knowledge transfer within such cluster also benefits mature innovators[32]. These roles are played by science park members to promote the industrial clustering of Taiwan.

The world is witnessing a shift from real economy to digital economy. Many environmental characteristics of the real economy will undergo revolutionary changes under the digital economy. Current systems of industry–academia cooperation are still aligned with the needs of the real economy and manufacturing R&D, and aim for patent or technology transfer, rather than focusing on economic activities that involve experiencing and testing technological services or experimenting with business economic models. Given the international development trends, except for software/hardware collaboration projects, the content and structure of industry–academia cooperation are also changing; therefore, industry–academia operations in Taiwan, including contents and mechanisms, should be brought into line with international development trends and appropriately adjusted so that more business innovations can be developed into economically beneficial service models through pilot testing.

In contrast to the United States' experience of developing Silicon Valley, the development patterns of science parks with software and services at the core are slowly changing the development trajectories of future science parks. In terms of links between smart cities and science parks in Europe, science parks have been established as the main pillar of smart city development. The development elements required for a smart city, including smart transportation, smart manufacturing, and innovative applications, all underline the vital role that science parks have to play. Therefore, the development of future science parks in

[31]Hendry, C., Brown, J., DeFillippi, R., 'Regional clustering of high technology-based firms: Opto-electronics in three countries', Regional Studies, Vol 34, No 2, 2000, pp 129–144.
[32]Chi-Hua Wu, Ting-Lin Li, Hsieh-Sheng Chen, Po-Cheng He (2012). Industrial Clustering and Regional Innovation: Theory and Evidence of Economies of Agglomeration. New Taipei City: Future Career Publishing.

Taiwan must be focused on determining ways for next-generation science parks in Taiwan to join forces with neighboring industrial parks and tackle issues concerning urban development, frontier technology applications, and circular economy development.

(2) Response Strategies

A. Re-examine the industrial structure of Taiwan and foster next-generation industries

(A) Re-examine the industrial structure of Taiwan, support the fostering of industries that possess relevant technologies or invest in industrial planning research that paves the way to innovation and R&D, which drives the sprouting of next-generation technologies and facilitates the return of new technology industries to the market.

(B) Promote digital and net-zero transition, starting with key businesses to small and medium-sized enterprises (SMEs), and ensure the sustainable development of these key businesses and its systems under the dual transformation trend; for example, develop a distributed green energy digital management system that places park-level energy storage and renewable energy systems at the core, to build a virtual power plant in the science park and ensure uninterrupted production in key S&T industries, all the while providing park members with access to carbon credits through a new energy management framework.

B. Expand international exchange to cultivate international talents for next-generation technology industries

(A) Offer customized technical support to encourage international startup industries to set up research base in Taiwan, where they will conduct research on new technologies and create and test prototypes, thereby becoming a member of the industry supply chain; meanwhile, provide policy support that will help new technology industries to formulate international standards and treat Taiwan as the central base in Asia for testing new technological products.

(B) Build a pool of highly skilled workers by using platforms that drive exchange between startups and large corporations in various countries, and leverage opportunities derived from the exchange platforms of international science parks to compete for more human resources for Taiwan from international next-generation industries.

(C) Cooperate with international strategic parks under the system framework of international science parks and through private companies and government policies, and aim to partner with various new technology industries to strengthen the circulation of technologies and talents between parks, thus further accentuating the international importance of Taiwan's science parks.

C. Reinforce Taiwan's R&D capacity to develop new technology industries that are characteristics of Taiwan

(A) Keep abreast of the dynamic status of technologies and industries in various countries so that immediate actions can be taken when a situation occurs that will impact Taiwan.

(B) Build new technology industry capabilities that are specific to Taiwan so as to prepare the country for the fast-changing geopolitical and global economy situations; for example, set up a world-class base for transforming next-generation strategic technologies into practical applications—the base will provide world-class infrastructure, leverage advantageous resources, draw foreign R&D talents to Taiwan to develop semiconductors, quantum technologies and other value-added applications, thereby elevating Taiwan's autonomy and international status in next-generation strategic technologies.

(C) Tap into the innovative technologies in which Taiwan has invested, to strengthen the extent to which S&T and R&D models in Taiwan contribute to world industries and to develop new technology industries that are characteristics of Taiwan.

D. Strengthen industry–research collaboration, encourage originality in inventions, and fortify Taiwan's innovation capability

Strengthen the commercialization of original inventions by research institutions, develop a new industry–research collaboration system, fortify the link between science parks and results produced by higher education startups, and incentivize the creation of startup companies and various industrial science parks; meanwhile, provide collaboration platforms and opportunities to accelerate the commercialization of startup companies that contribute original inventions so that industry–research collaboration in Taiwan is slowly transformed into one that seeks originality in inventions, which will increase the value of technological R&D. In doing so, the original inventions developed through Taiwan's scientific research system can be commercialized into marketable technologies and products, thereby fully utilizing the role of science parks as a promoter of originality in research.

E. Strengthen ties within neighboring startup ecosystems to develop inclusive science parks

(A) Co-create a general solution for industrial, urban, and social innovation by optimizing the parks' innovation ecosystem, enhance the network of cooperation on innovation resources in the park, creating an environment and atmosphere that drive open innovation, improve the innovative businesses that stationed in the park, establish a systematic regional innovation capability survey, and encourage science parks to actively participate in local smart development programs, which will promote the balanced development of a region and grant opportunities for exchange in smart urban–rural development plans to help science parks forge stronger international ties and create more opportunities for park members to participate in international pilot operations. In doing so, science parks will become aligned with local smart urban–rural development plans and a key provider of technical solutions.

(B) Science parks are a critical action-taker in the regional helix model (government, academic and research institutions, industrial sectors, and civil society) of smart specialization. With this role in mind, connect science parks to different participants, consolidate the consensus of members in the region to facilitate policy planning and implementation, and provide services to institutions outside of the park to foster deeper innovation and cooperation for the parks and attract the clustering of new industries and outstanding talents.

(C) Science parks are also a link to external entities. With this role in mind, develop digital and net zero systems for industries, starting with science parks, to create relevant ecosystems; construct an open innovation service platform that crosses park boundaries, regions, and borders, and leads the interdisciplinary cooperation of high-tech industries; introduce innovative software services, strengthen digital and innovation capabilities, use a more flexible, open education system to cultivate highly skilled workers for the future, and also provide a reference for improving the education system outside the park; fortify relationships with non-park member industries to promote, through business sector's cooperation mechanism and public–private collaboration in different science parks, the transformation of future key S&T R&D results into innovative businesses for each science park, and help tackle challenges that science and industrial parks are facing at the moment, including low-carbon transportation, information security management, and green energy supply.

4.3.3 Digital Economy

(1) Problems and Challenges

A. Authorities in charge of digital assets have not yet been established, laws and regulations on digital assets are incomplete, ministerial input is required to contemplate cross-industry applications

Obstacles impeding the development of Taiwan's trustworthy technologies and digital assets include ill-defined sources of law and regulatory agencies. For example, fintech companies are within the jurisdiction of the Ministry of Digital Affairs, rather than that of the Financial Supervisory Commission. In the future, the Ministry of Digital Affairs will oversee the development of fintech industries; therefore, how authorities in charge of supervising fintech industries will work together has become a grey area in future development.

Presently, the assistance that digital economy operators need from the government includes data use and supervisory mechanisms. For fintech operators, applying for the use of various data has been difficult and expensive primarily because of the ambiguous laws and regulatory roles.

Another obstacle is the adoption of tight policies that discourage fintech operators from entering the regulatory sandbox and provide them with limited space for experimentation and development. The Financial Supervisory Commission has a mature regulatory sandbox and innovation concept verification mechanism in place; in which case, the Commission can consider expanding the scope of application and lowering entry threshold to accommodate the application of more digital assets and trustworthy technologies in practice, which in turn encourages the development of innovative digital asset applications and service models.

As opposed to laws for traditional assets and accounting practices, laws for digital assets are not clearly defined and enforced in various countries. Because the use and sale of assets involve amendments to tax and accounting laws, other ministries, in addition to the Financial Supervisory Commission, should also have a role to play, and the regulatory authority should be determined as soon as possible to expedite the development of the digital industry.

Given the restrictions that other countries impose on the privacy and use of personal information, Taiwan should review the approaches it adopts to improve the process of de-identification, and also comply with the design specifications of international laws (e.g., European Union laws), investigate the principles of using and protecting the personal information of international persons, and provide an innovative regulatory environment for the benefits of industries.

Except for a financial regulatory sandbox, regulatory sandboxes for other industry technologies are seldom used in Taiwan. Taiwan should actively set specific goals for the development of new technologies, urge industries to plan application scenarios and regulatory sandbox requirements, and examine the possibility of developing its digital economy models on an international scale so as to invest key resources to promote relevant development.

B. Taiwan could emulate other countries to clarify its digital asset storage management systems

Differences in the ability of companies to manage technological risks will negatively affect industrial development. For example, biometrics may produce different errors (e.g., acceptance and rejection error rates) in different financial systems, which in turn generate new technological risks. Each bank has its own composition and risk-taking capabilities, causing potential differences in relevant developments. The definition, scope, and storage management methods of financial transaction data also affect industrial and economic development. For instance, when a financial institution or third-party service provider collects customers' personal data, the data management mechanism and usage restrictions require government intervention. In countries such as the United Kingdom, some European financial industry data centers were relocated from London to Frankfurt, New York, and other places after Brexit to comply with European supervision regulations. In China, authorities enforce restricted data residency management, forming an alternative mechanism to protect its domestic industries. Following the implementation of the General Data Protection Regulation (GDPR), the European Union has published European data strategies and artificial intelligence white paper to provide the highest guiding principles for automated decision-making. Although the principles are reasonable and in line with existing views on technologies, they are somewhat overly stringent or difficult to implement. Nevertheless, the principles remain of considerable value as reference for relevant issues.

C. Social infrastructures in Taiwan are not resilient enough to mitigate risks of uncertainties

There will be risks of uncertainties in the social and economic security of Taiwan. These risks must be mitigated as early as possible through investments in science and technology. Taiwan should think about building, maintaining, and developing resilient social infrastructures that integrate both software and hardware components in order to strengthen its capability to operate agile response systems and various key infrastructures, facilitate future risk management, improve the resilience of social operations, and ensure that Taiwan is able to tackle any risks in the future.

The digital economy depends on a good, effective infrastructure; therefore, managing all types of infrastructure and ensuring the reliability of its operation became the centerpiece for Taiwan to develop a resilient society. For this reason, Taiwan has been promoting the digital economy by adopting measures that mitigate all types of systematic risks. In the future, Taiwan should reinforce the management and operation of any infrastructures that affect the resilience of the society, such as power lines, water supply pipelines, submarine cable systems, health and social care systems, etc. Thus, the country's infrastructures will be as reliable as its international counterparts and play a key role in protecting the basic social operations of Taiwan.

(2) Response Strategies

A. Devise plans to develop a sound digital management system and laws and build an environment that is conducive to the application of trustworthy technologies and digital assets

(A) Strengthen the collegiality mechanism between ministerial departments and ramp up digital transformation efforts to establish regulatory functions that fortify the trust relationship between the government and the people.

(B) Help citizens to better understand the importance and value of their personal data and to seize control over their own data, build a direct trust relationship between trading entities, and promote the development of decentralized trading structures to improve trust among participants in the digital economy and reduce transaction costs.

(C) Strengthen S&T risk governance regulations in line with industrial development to include cybersecurity, information service outsourcing, digital banking monitoring, audits, and other scenarios in the scope of governance; for example, formulate laws and regulations on advanced digital assets and distributed ledger technologies.

(D) Prioritize building a digital identity system, emulate UK's digital management approaches, integrate ESG practices into digital management policies, encourage and support the development of local, small and medium-sized, and domain-specific venture capitals, establish venture capital businesses, and provide development opportunities for startup SMEs.

(E) Formulate and establish relevant laws and regulations based on regulatory needs, and concurrently establish competent authorities and regulatory frameworks and rules for them.

B. Urge world-class digital economy companies to set up R&D base in Taiwan to strengthen the country's software services and cybersecurity capability

(A) Urge cutting-edge technology companies to set up R&D base in Taiwan to strengthen the country's software technologies; adopt market mechanisms to help Taiwanese software companies gain international recognition; enforce policies that encourage world-leading companies to cooperate with local companies, and strive to create world-class service platforms and software services.

(B) Adapt Germany's higher education–industry interaction model to integrate the strengths of German systems, and rebuild Taiwan's higher vocational education system.

(C) Form an international, interdisciplinary team of highly specialized experts with potential for market development to plan and develop scenario applications and promote the development of software and cybersecurity industries; introduce special technology application facilities that match the economic patterns of Taiwan, promote their application, invest initial funds for industrial development, and introduce feasible international application scenarios; leverage the advantages of software and hardware integration, and expand the market quickly to boost the development of Taiwan's software industries and relevant technology application industries; connect to the world's digital capability by shifting from single-point entry to nationwide expansion, urge major international manufacturers to establish their R&D base and digital platforms, conduct R&D, and train talents in Taiwan, and guide upstream and downstream suppliers in Taiwan to connect their platforms or form a network of systems, with Taiwan as the test base and the starting point of supply chain integration so as to transform Taiwan into an integrated cluster of advanced manufacturing supply chains representing democratic countries.

(D) Promote smart manufacturing service export by strengthening the capacity of software and information services, assist the manufacturing sector to analyze and predict customer demand trends so as to keep abreast of customer demands in overseas niche markets, and motivate manufacturers and digital service providers to jointly create a business model that establishes global presence for smart manufacturing services, thereby raising the salary level of the industry.

(E) Ensure that export services incorporate the output value of manufacturing industries and increase the wages of the domestic manufacturing service industry; strengthen cybersecurity for software and hardware services by establishing an internationally recognized cybersecurity certification framework, develop cybersecurity-certified software, which will assist professional third-party audits to provide a benchmark for the international development of Taiwan-based cybersecurity companies; and continuously improve the services and contents of platforms that were established through S&T plans, introduce foreign investments from friendly countries, set up cybersecurity venture capital funds, and build an international cooperation platform, which will be used to guide cybersecurity-certified companies in Taiwan to make investments and meet international standards; and cultivate internationally recognized cybersecurity service providers to strengthen cybersecurity resilience and the information security of industry software and hardware services, thereby improving the service capacity and promoting the export capability of Taiwan's cybersecurity industry.

C. Develop a distributed smart living scenario real-time response system, facilitate integrated use of smart patrol, sensor, and IoT technologies, and use artificial intelligence to develop early warning analysis technology and reduce the risks of natural disasters such as earthquake and storms

(A) Create a sensor fusion environment integrating existing sensors and IoT technologies to strengthen the self-decision-making capabilities of various traffic signs and pipeline systems; manage resource allocation with AI technology to speed up disaster prevention and early warning time, and use sensor fusion analysis technology to integrate unmanned vehicle technology, develop last-mile precision delivery capability, and strengthen intelligent empowerment for infrastructure upgrade and improvements.

(B) Integrate information between different devices and systems, strengthen the capability of various systems in Taiwan to mitigate risks and disasters, and develop an agile response system that is characteristics of Taiwan to ensure the continuous operation of various social and economic activities in Taiwan; capitalize on science and technology to empower decision-makers to take command, quickly resolve disaster impact on everyday activities, and enhance the continuity of the society.

4.3.4 Green Economy

(1) Problems and Challenges

A. Inventory of emission-reduction technologies is lacking and elaboration on policy instruments should be planned as soon as possible

Early-stage issues concerning the green economy, including local pollution and environmental problems, have become complex global concerns that involve international trade and supply chains. Taiwan will need to integrate resources from various sectors, focus on developing energy conservation and emission reduction technologies, and adopt S&T innovation to help business operators in Taiwan take carbon actions. SMEs in Taiwan are not as capable as large companies to address international carbon reduction issues; they will need guidance and assistance from the government. Therefore, developing a guidance mechanism that helps business owners to adopt relevant technologies is a policy focus in Taiwan. At present, Taiwan has yet to formulate precise green economy policy guidelines and to further improve its experience in using policy instruments such as carbon tax and dividend. The country needs to plan relative response measures as early as possible. In addition to designing control measures, using financial technology to drive behavioral changes in the business sector is also important. Taiwan must therefore brace itself for various challenges and issues that will be derived from the green economy and industrial transformation, which include adopting more policy instruments to incentivize the business sector to take carbon actions so as to advance Taiwan toward a green economy that not only drives the reduction of GHG emissions in the manufacturing sector but also promotes the development of new technology and service industries such as green finance and green technical services, etc.

B. Taiwan is lacking a carbon footprint inventory mechanism, experts with audit skills and knowledge, and a comprehensive ESG-related certification package

Taiwan needs a mechanism to take inventory of and track inputs and outputs, as well as monitoring indicators that can provide a basis for snowball-based review. We also lack experts with advanced degrees, skills, and knowledge in carbon footprint inventory and auditing. Under the global trends of net zero emissions and the Carbon Border Adjustment Mechanism (CBAM), transitioning to net zero emissions is no longer merely an environmental issue but also an economic one that critically affects the international competitiveness of Taiwan-based industries. In 2022, the Financial Supervisory Commission strengthened the disclosure rules for reporting ESG-related information in corporate annual reports and expanded the scope of third-party assurance for the sustainability reporting of TWSE/TPEx-listed companies. In light of such enforcement, increasingly more Taiwanese companies will pay more attention to ESG-related governance issues.

In the future, Taiwan should speed up corporate accounting-related reporting and establish a government-recognized carbon footprint inventory method that integrates carbon footprint inventory technologies, employee training, regulatory requirements, and business operations, in order to fully transition into a zero-carbon economy in response to the GHG and carbon footprint control requirements imposed on the world's business environment. Presently, there is a significant shortage of talent in these fields, both in Taiwan and worldwide. How to meet the huge industry demand in a short period of time will also be a crucial problem that Taiwan needs to overcome in the midst of developing its green economy.

(2) Response Strategies

A. Ramp up investments in new energy technologies, and build a platform that facilitates industry–research collaboration on net zero emissions and green energy audit services to meet energy transition goals

(A) Actively develop other new renewable energy technologies to meet the world and Taiwan's energy transition goals; promote an energy technology strategy that places emphasis on the development of technological applications, set up hydrogen-related infrastructure to popularize the use of hydrogen as energy, and integrate it with hydrogen energy storage systems to support the structural characteristics of renewable energy in Taiwan; promote various energy-saving processes and technological applications so that Taiwanese industries outperform the world in terms of energy efficiency and effectively conserve energy in overall power supply; step up research and investment efforts on undeveloped renewable energy that shoes development potential, such as hydrogen/ammonia, marine energy, and geothermal energy, to create a system of renewable energy that is specific to the environmental conditions of Taiwan; and establish a comprehensive platform for net-zero carbon emission-related technology research and development and industrial application, play the role of leading the small, the industry will work together to create development, and reduce the pressure and risk of enterprises in response to international trends.

(B) Establish a net zero emission technology R&D and industrial application platform which will encourage large companies to set an example for small companies in cooperating with industries on co-creation and development initiatives, thereby helping the business sector to reduce the pressure and risks of responding to international trends.

(C) Establish a model that connects industries that use digital technology for energy transition to government demand, and increase the willingness of industries to adopt/proportion of industries that adopt digital tools and net zero emission technologies; use platform models to fortify the connection between technological development and industrial applications; encourage large companies to lead SMEs in adopting and applying renewable energy technologies, thereby strengthening net zero actions in Taiwan.

(D) Build an inter-ministerial green energy audit service platform with reference to the world practice of adopting artificial intelligence, IoT, and blockchain technologies to provide energy audit services, and use the platform to supply information for compliance with domestic and international laws and regulations; adopt relevant technologies to introduce GHG and carbon footprint inventory, which then serve as a platform for assisting SMEs with green energy transition to reduce problems associated with the cost of energy transition and technology adoption; and collect production-related information from the business sector to provide a basis for promoting next-generation green energy industries and policies, and use a public platform to develop technology-based green energy audit services that are shared across and applied by industries.

B. Increase training mechanisms to build a talent pool of green collar workers

(A) Improve the education and vocational training systems at all levels to include training and international certification mechanisms for green talents, and connect them to internationally recognized green industry professional certificates, so that there are human resources to develop Taiwan's green economy.

(B) Set up training courses through consulting firms, industry-based colleges, and institutions as a short-term measure; as a medium/long-term measure, encourage universities to establish schools, departments, institutes, or degrees related to the green industry to supply the needed talents; and strengthen on-the-job training, and provide assistance to those who have been negatively impacted to avoid structured unemployment in the future.

(C) Build an international talent training base for regional green industries, and integrate it with international practices; for example, combine the experiences and strengths of Taiwanese vendors in green energy technology and utilize higher education resources in Taiwan to build a key talent pool that facilitates the green economic transformation of emerging countries.

(D) Vie for green transformation business opportunities in Southeast Asian countries through domestic enterprises; for example, become Asia's offshore wind power talent training center, Southeast Asia's optoelectronic integration application training center, or a world-class industry talent training base to train green-collar talents for Taiwan and Asia.

4.4 A Circular Zero-Carbon Environment

Climate change has resulted in more frequent and more intense extreme weather events. Waste and pollution generated by the rapid depletion of energy resources have seriously impacted human life and property and the earth's ecological environment, threatening human health and survival. The world is fighting against climate change and becoming more aware of the importance of environmental protection. As of the end of 2022, more than 130 countries had announced net zero or carbon neutrality targets33.The European Green Deal (EGD) aims to achieve the long-term goal of "zero emissions, zero waste, and zero pollution" by 2050 and the mid-term goal of reducing carbon emissions by 55% by 2030. The European Union also successively implemented a range of key policies such as the carbon trading market (market mechanism), CBAM (trading), and sustainable investment framework (financial instrument). Given these situations, major economies began charging carbon tariffs in recent years, while global supply chains began imposing more stringent requirements for carbon reduction, and economic activities must meet the taxonomy regulation and take into consideration climate change mitigation and adaptation actions as well as environmental impact. To tackle challenges from climate risks, green supply chain requirements, and bottlenecks in the supply of key energy resources, Taiwan must strengthen the deployment of decarbonization technologies, promote the recycling and reuse of energy resources, leverage its ICT strengths, fortify climate governance, and improve its disaster prevention and reduction capability to construct a robust, reliable and affordable energy supply resilience system and create a green living environment that is conducive to the health of Taiwanese nationals.

An overview of the environmental development needs of Taiwan by 2035 reveals that to achieve net zero emissions, Taiwan must focus on five key issues: circular economy, energy transition, supply and management of key energy resources, climate change risks and adaptation, environmental resource governance and ecological restoration. Specifically, by 2035, Taiwan must strengthen energy resilience and climate governance, achieve a circular economy, adopt net-zero technology, and achieve digital sustainability to strive toward sustainable development and a One Health environment. The problems and challenges of each issue and counterstrategies are described below.

[33]Net Zero Tracker, URL: https://zerotracker.net/.

4.4.1 Circular Economy

(1) Problems and Challenges

A. The practice of linear production and consumption remains unchanged, NIMBY facilities pose a challenge to circular economy policies

Environmental laws and regulations in Taiwan are based on stringent international standards. Consequently, many high-value byproducts cannot be reused as resources. Regulatory compliance increases handling costs, causing manufacturers to lose the economic incentive for recycling and transfer the cost onto consumers. For example, sea-sand building incidents in Taiwan prompted the government to amend laws, which made it difficult for cement made from recycled materials to meet the CNS 3090 standards. There is also no statute of limitation for prosecution in environmental laws and regulations. According to Article 30 of the Waste Disposal Act, when upstream operators fail to properly check waste and harmful substances, midstream and downstream operators that use these substances may be affected. Regulatory restrictions are also a deterrent for large R&D companies, while small factories struggle to dispose of waste effectively and legally using traditional methods. For example, basic-oxygen-furnace slag, a by-product of the iron and steel industry, is sturdy and durable when used in public constructions; however, it cannot be effectively used because of regulatory requirements and environmental conditions.

B. Inadequate energy autonomy makes industry chains more vulnerable to risks, and there is still a gap in scientific research and industry demand

Taiwan relies heavily on imported energy. Geopolitical factors have hindered progress in diplomatic matters such as negotiations on imports. Bilateral trade and industrial exchange and cooperation with other countries are variable, negatively affecting the stability of industry chains. For this reason, Taiwan needs to promote energy recycling to increase and secure its energy supplies. Resources such as precious instruments of academic and research institutions are not concentrated. Test samples from industries are prone to contamination during transportation process, which affects experimental reproducibility, making it difficult for researchers to meet industry standards or effectively perform analysis and correction. Protecting the intellectual property and confidentiality of S&T outputs of the circular economy are also imperative. For students who are part of an industry–academia collaboration program, they will need a more flexible education system in order to obtain a degree without infringing intellectual property rights.

C. The internalization of product external product costs should take into account the cost of environmental impact and impact on human health

A company incurs not only operating costs, but also external costs generated from environmental and health impacts. Process byproducts are treated as waste and so are not properly recycled as resources, which increases treatment costs, intensifies energy consumption and carbon emissions, and may affect the ecosystem or human health, all of which are detrimental to the promotion of a circular economy. Waste-related news creates negative impressions that cause the general public to oppose waste disposal sites, further impeding the promotion of circular economy industries.

(2) Response Strategies

A. Emphasize sustainable production and consumption to fully realize a circular economy in industrial and social systems

(A) Amend laws and regulations on the criteria for recycling and using high-value byproducts, and set a reasonable evidence-based limit on the content of hazardous substances; task environmental authorities with discussing conditions that exempt downstream waste users from joint liability when the limit on the content of hazardous substances is exceeded.

(B) Increase the willingness of the business sector to help Taiwan promote a circular economy, such as by providing reasonable profits and environmentally friendly practices, which will boost corporate reputation, thereby accelerating the sustainable production and recycling of energy resources.

(C) Focus on relevant key technologies, such as hazardous substance ceiling concentration real-time analysis technology, refuse-derived fuels, biomass materials, technologies that recycle wastes as resources to increase the value of wastes, secondary raw material applications, technologies that increase the use of secondary raw materials, recovery of leftover materials, building materials that are easy to recycle and reuse, and urban waste heat recovery.

B. Develop material recycling technologies, sustainable designs, and new business models, and encourage talent development through industry–academia cooperation to promote net zero transition across industries

(A) Transform state-funded green energy research institutes, International Circular Material Academy, and circular material innovation R&D centers into a world-class circular economy paradigm center by integrating the phases of the technology readiness level (TRL) method; engage in S&T diplomacy using circular economy scientific research results, and engage in technology export and economic and trade negotiations with countries whose market has demand for technologies; continue to promote experimental education in science parks and encourage industries to invest directly in higher education institutions; further expand and expound on measures relevant to the MOE Industry–Academia Cooperative Ph.D. Project to fortify links between talents and industries.

(B) Focus on relevant key technologies, such as decarbonization methodology, alternative raw materials, zero-waste closed circular product designs, material life cycle management, recycling and decarbonization technologies for the agricultural sector, and Carbon capture, utilization, and storage (CCUS).

C. Integrate incentive measures into circular economy policies to ensure a sound circular economy market mechanism

Enforce laws and policies and offer incentives or rewards as a means of guiding industry operators to recycle and use process byproducts or wastes; amend laws to assign cement, steel, paper-making, and petrochemical industries with tasks that will prompt companies that value ESG and reputation to willingly disclose information on waste generation, which in turn inspire startup teams to invest in waste innovation and utilization industries; raise the awareness of forestation in both private and public sectors and encourage regional revitalization to introduce a positive ecosystem that drives innovation; adopt sustainable investment concepts to boost the development and integration of resources through direct (funding assistance) and indirect (financial measures) input model.

4.4.2 Energy Transition

(1) Problems and Challenges

A. Taiwan is heavily dependent on imported fossil fuel, which has created an energy crisis and carbon emission problems; the country urgently needs to develop low-carbon energy technologies, secure a stable source of renewable energy, and promote structural energy transformation

In 2021, the dependence on imported energy in Taiwan was 97.44%, with fossil fuel being the main source of energy consumed for electricity generation, resulting in a high volume of GHG emissions. The country must, therefore, actively develop methods of using new renewable energy and low-carbon energy by improving energy technologies and adopting new energy technologies to facilitate the structural transformation of its energy supplies. Scientific research systems need to be strengthened as well through interdisciplinary integration and cooperation between industry, academic, and research institutions to apply R&D results in practice.

B. High renewable energy penetration rate will affect grid stability and electricity dispatch, thus impeding green energy development

Current power supply systems are moving toward wind–solar hybrid systems; however, grids in Taiwan are isolated and centralized, which easily causes large-scale power outages due to problems with voltage balance. Adopting high-penetration renewable energy, which is associated with grid stability issues, might further intensify power stability problems. Insufficient system inertia will also put a strain on the dispatching of electricity. To accommodate high-penetration renewable energy, power grids must be made more flexible and resilient.

C. In the face of challenges in green supply chains and carbon tariffs, ministerial departments of Taiwan are grappling with meeting emission targets in time to achieve net zero emissions by 2050

The industrial, residential, commercial, and transportation sectors are the main emitters of GHG, considering both direct emissions and emissions from purchased electricity. New technologies must be adopted to increase energy and resource efficiency, develop low-cost energy management systems and monitoring and measurement methods, to slow energy demand growth.

(2) Response Strategies

A. Develop pioneering technologies for the use of new renewable energies and low-carbon energies to build a low-carbon power supply system

(A) Research and develop decarbonization technology to develop a low-carbon power supply system and develop pioneering technologies for the use of new renewable energies and low-carbon energies; improve technological deployment, produce green hydrogen locally from green electricity that cannot be dispatched, develop advanced hydrogen and ammonia production, transportation, and storage technologies, and strengthen hydrogen/ammonia supply chains and energy supply security.

(B) Focus on relevant key technologies: Frontier renewable energy technologies or zero-carbon technologies that ensure stable supply (e.g., deep geothermal energy and Ocean Thermal Energy Conversion

(OTEC) technology), nuclear fusion and relevant technologies developed through international cooperation, and hydrogen/ammonia gas supply chain-related technologies and applications such as high-performing technologies that produce hydrogen from renewable electricity, hydrogen/ammonia transportation technologies, composite materials for hydrogen storage, blended hydrogen–natural gas-fueled combustion engines, technologies that produce hydrogen from natural gas pyrolysis, and bio-energy with carbon capture and storage (BECCS).

B. Optimize the resilience and flexibility of electricity systems, develop digital power management and energy storage devices, and strengthen disaster prevention capability

(A) Increase the resilience of energy systems to prepare for a future of high-penetration renewable energy; cultivate the capability to develop new energy sources independently, carry out R&D works on energy storage and hydrogen conversion systems so that hydrogen will account for at least 10% of Taiwan's energy mix in the future, and conduct research on innovative energy storage materials to prepare for Taiwan's large energy storage demand in the future.

(B) Develop flexible AC transmission systems with stable grid voltage and frequency, strengthen smart grid technologies required for dispatching green power, develop high-efficiency grid-level energy storage equipment and safety enhancement technologies, adopt incentivized electricity market mechanisms to solve grid stability problems that may occur with high-penetration renewable energy as a result of insufficient inertia or extreme weather events, and provide stable low-carbon electricity for various industries to meet international supply chain carbon reduction requirements and bolster industrial competitiveness.

(C) Amend the Renewable Energy Development Act and Electricity Act to enhance the applicability of energy storage and implement supporting measures so that energy storage companies may cooperate with renewable energy generators or sell electricity independently and that the energy storage systems installed by energy storage companies or high electricity users can be incorporated into the electricity trading market.

(D) Focus on relevant key technologies: smart solid-cell electrical substation technologies; advanced smart grid technologies, such as distributed microgrids, ICT-empowered smart grid technologies, and distributed power supply systems; renewable energy power smart dispatching technology, flexible AC technology; grid resilience enhancement technology and disaster prevention enhancement; pioneering grid energy storage technology, such as frontier grid energy storage system, battery cell optimization technology, battery safety enhancement technology, solid cell technology, safe car batteries, fuel cell, and flow battery.

C. Improve resource efficiency to slow energy and electricity demand growth

(A) Capitalize on Taiwan's strengths in the fields of ICT, perform analysis and prediction by using artificial intelligence, AIoT, digital technologies and big data to develop high-efficiency energy and electricity management systems, which can be used in conjunction with auxiliary services to balance energy supply and demand, smooth electricity demand curves, promote efficient use of electricity, slow energy and electricity demand growth, and develop low-cost energy management systems and monitoring and measurement methods.

(B) Focus on relevant key technologies: decarbonization technologies such as hydrogen direct reduction steelmaking, low-carbon thermal insulation construction materials, fuel cell carriers, hydrogen energy carriers, and safe energy storage technologies for vehicles.

4.4.3 Supply and Management of Key Energy Resources

(1) Problems and Challenges

A. COVID-19 and war, among other international events increased the risk of supply chain disruption

The International Energy Agency warned of supply challenges facing raw materials for climate change related technologies. Clean energy technologies have greater demand for critical minerals compared with fossil fuel based technologies. In addition, the Covid-19 pandemic, Russia's invasion of Ukraine, and geopolitical factors have exerted a significant impact on supply chain security and generated supply disruption risks.

B. Taiwan relies on imported energy, making domestic industries vulnerable to the external environment and international events

Energy sources such as natural gas in Taiwan are mostly imported. If Taiwan's dependency on imported energy increases continuously, the country will be susceptible to impacts from the external environment, international events, and geopolitical factors, which increase supply risks. According to the KPMG 2021 CEO Outlook in Taiwan, supply chain risk ranked No. 1 among the five main risks influencing Taiwanese companies. In addition, the increase in the scale and frequency of droughts and floods due to climate change necessitates effective water resource management.

C. The lack of critical mineral recycling and reuse mechanism warrants strengthened energy resource management to ensure autonomy in critical energy resources

Taiwan ranks fifth in the world in terms of demand for rare earth elements (REEs). Rare earth imported each year into Taiwan is primarily used in rare earth magnetic materials for permanent magnet motors, polishing powder, fluorescent agents, and metallurgical and cell alloy components. The scope of application of rare earth is mostly industries such as energy, electronics, automobile, national defense, and biomedicine, directly or indirectly affecting billions of output. Semiconductor and high-tech industries in Taiwan use a substantial amount of REEs, with semiconductors and ICT products requiring more than 1,000 tons of REEs each year, which are mostly imported from China and Japan and highly concentrated geographically. Geopolitical factors may drastically affect ICT industries in Taiwan.

Presently, Taiwan lacks a complete chain of industries that are self-sufficient in rare earth and lacks the ability to control the supply of critical minerals.

(2) Response Strategies

A. Build a regulatory framework for supply chain security management to improve critical energy resource supply mechanism

(A) Strengthen the security of critical energy resource supply chains by emulating the approaches of advanced countries. For example, the United States enforced the Defense Production Act of 1950 to support critical mineral supply chains for clean energy development, announced a policy to improve the resilience of U.S. supply chains, and created a Supply Chain Disruptions Task Force to solve short-term supply chain disruption problems. Tech giant Apple developed a family of robots (Daisy, Dave, and Taz) to dismantle and recycle materials for remanufacturing (product cases are made of 100 percent recycled aluminum) and built a gold supply chain of exclusively recycled materials to ensure the management of critical materials, thereby further increasing the stability, flexibility, and economic benefits of the supply chain.

(B) Focus on relevant key technologies: Deep learning for automatic recognition algorithm; blockchain for assistance with keeping track and monitoring of raw material inventory, and effective recycling and reuse to ensure supply chain security; and data analytical technology combined with cloud platforms for critical material monitoring.

B. Develop alternative energy resources and materials to promote the recycling and reuse of critical energy resources in industries

Adopt green, circular designs and recycling concepts to develop products that can be disassembled, recycled, and reused to reduce waste; utilize residual energy or resources (including byproducts or wastes) from production processes and reuse them by using remanufacturing or resource recycling methods; develop green energy technologies, products or equipment that combine alternative materials or use alternative resource processes; and actively develop innovative technologies and designs that more effectively recycle and reuse critical energy resources.

C. Develop innovative technologies and innovative designs, cultivate talents, deepen the security of critical energy resource supply, and strengthen industry autonomy in critical energy resources

(A) Ensure the sustainable supply of critical minerals in Taiwan, diversify sources of critical minerals, and strengthen storage mechanisms; develop technology-intensive secondary intermediate products (critical materials) and value-added products or application products that have growth potential; strengthen the ability to take proactive steps in critical energy resource management and to adapt it in real time—for example, the U.S. Critical Materials Institute cultivated talent and developed new extractants for diglycolamine (DGA) ligands, which is superior to current rare earth recycling techniques.

(B) Provide material recycling companies with R&D subsidies, tax reductions, or better incentives that will encourage them to invest resources in R&D technologies and support the development of recycling industries, thereby enabling critical energy resource supply chains to be self-sufficient in the supply of raw materials, which subsequently boosts industrial development, enhances industry autonomy, and truly realize a circular economy.

(C) Manage water resources from multiple dimensions, such as increasing sources of water resources (desalinated seawater, recycled water, subsurface water, etc.), increasing reservoir water storage capacity, and adopting smart water conservation measures; thoroughly implement runoff distribution and runoff control, and set up water storage and flood detention facilities in buildings to conserve water and reduce consumption; and strengthen water resilience in urban development through engineering and land planning.

(D) Focus on relevant key technologies: non-rare earth permanent magnet materials and technologies; electrodeposition rare earth recycling technologies; new seawater desalination technology for energy conservation, which is more efficient and cost-effective, such as next generation high-pressure diaphragm pumps; seawater desalination during the drought period of water reservoirs, which ensures more efficient water supply and energy conservation; new drone-integrated cloud seeding technology; water pipes (for water dispatching) connected to reclaimed wastewater, which is produced by treating domestic wastewater; water conservation technologies, such as IoT technology for water consumption management, adoption of water for precision agriculture, old pipe repairs to reduce water leakage, and water consumption detection to prevent hidden water leaks, which cannot be treated immediately.

4.4.4 Climate Change Risks and Adaptation

(1) Problems and Challenges

A. Climate governance mechanism must be enhanced to achieve net zero emissions in time

The government of Taiwan is currently amending the Greenhouse Gas Reduction and Management Act into Climate Change Response Act; however, more proactive steps need to be taken to achieve net zero emission goals by 2050, such as increasing the hierarchy of climate governance, adding clauses on climate change adaptation, reinforcing emission control and incentive mechanisms, promoting reduction, and levying carbon taxes, etc. In addition, relevant legal systems must still be discussed and reviewed to perfect climate laws and lay a foundation for the development of climate governance in Taiwan.

B. Climate and disaster prevention information and strategies are not properly integrated, which will hinder the localization of adaptation and proactive management

The world, including Taiwan, is committed to net zero emissions by 2050. Currently, climate science data and information are not integrated into climate change monitoring and adaptation strategies. This shortcoming makes it difficult to build a proactive management mechanism using technology and information integration, to strengthen resilience and spearhead lifestyle transition. Moreover, due to statistical scales, climate data and scenario simulation models often have to undergo quality control processes such as result analysis, deviation correction, and uncertainty analysis. In other words, these data and models must be effectively translated before it can be adopted in Taiwan to meet local needs and serve scientific research and disaster prevention purposes.

C. Extreme weather events are frequently occurring, elevating climate risks that threaten human health

In recent years, the frequency and intensity of extreme weather events have gradually increased, not only causing disasters and losses but also posing threats to human health. In the face of more serious public health challenges, the Taiwan government urgently needs to discuss policies related to the impact of climate change on health, devise plans to incorporate S&T capabilities into spatial planning, medical care and social welfare policies, strengthen disaster prevention, preparedness, and post-disaster response capabilities, and comprehensively improve the climate resilience of Taiwan.

D. Improved climate data governance system is required to reduce the impact on society and the living environment

New technologies and climate change are bringing unprecedented challenges. Science and data-based climate change mitigation, adaptation, and sustainable development strategies involve monitoring, proactive management, and the analysis and integration of voluminous data. For this reason, the Taiwan government must capitalize on its digital technologies to launch transformation strategies for innovation, inclusion, and sustainability. Meanwhile, data availability and accessibility must be actively promoted to adopt big data analytics and assist the central and local governments in discussing effective coping strategies and action plans that will optimize the living environment and reduce the impact on health and society as a whole.

(2) Response Strategies

A. Integrate net zero transition into S&T development and use interdisciplinary climate services to drive interdisciplinary climate

governance

Implant the concept of net zero transition into S&T-based regulatory policies to cement a foundation for climate governance development, and adopt a systematic thinking approach to discuss cross-sector climate service needs and integration mechanisms, promote interdisciplinary integration and coordination, and enhance the country's disaster preparedness and disaster prevention capabilities; meanwhile, consider local needs and global trends during climate scientific research and development to secure Taiwan's overall scientific research competitiveness.

B. Adopt nature-based solutions (NBS), initiate regulatory adjustment and expansion, drive interdisciplinary innovation and development, and build a pluralistic governance ecosystem

Speed up the process of revising laws and regulations relating to climate and energy, actively discuss, introduce, expand, and improve climate-related legal systems according to future development trends, conduct evaluation and surveys on carbon sinks (soil, forests, and ocean), and engage in conservation and restoration actions; meanwhile, launch action plans with the goal of climate change mitigation and adaptation in mind to create nature-based solutions.

C. Use appropriate technologies to integrate central and local authorities, and optimize living space to ensure the life and health of Taiwanese nationals, thereby realizing lifestyle transition

Use technologies to integrate the needs of each sector and promote integrated spatial development strategic plans and climate health policies; improve evaluation and monitoring technologies to mitigate disaster occurrence and impacts and enhance slope stability in the environment of Taiwan; meanwhile, build a strong pool of academic and research talents for Taiwan with advanced skills and knowledge in sustainable development and adaptation to climate change, and promote the mainstreaming of net zero sustainability awareness, which will accelerate the transition to low-carbon life and build a sustainable Taiwan.

D. Use data to drive and amplify Taiwan's capability and influence in scientific research to boost the development of new industries

Create digital incentives, promote the comprehensive digital transformation of the nation's infrastructure, implement data access, strengthen decision-making support and interdisciplinary collaboration, and promote international exchange and cooperation.

4.4.5 Environmental Resource Governance and Ecological Restoration

(1) Problems and Challenges

A. Relevant environmental IT systems must be integrated to bridge the gap in environmental resources or monitoring information

Deployed points of monitoring should be used to form a monitoring network, in which environmental survey and monitoring data are completely sent back to the database in real time so as to adopt and control environmental response measures more efficiently. However, there are many types of environmental resource databases, thus necessitating an information integration platform that incorporates relevant environmental survey and monitoring data to provide comprehensive and detailed environmental information.

B. Ecological problems must be addressed through conservation or restoration initiatives

A comprehensive survey of ecological diversity must be conducted to establish a national biodiversity database as soon as possible for ecological resource research, conservation, and utilization. Invasive alien species have caused a major problem to the ecology of Taiwan. Education or IT tools should be used to reduce invasive species. In addition, regulatory mechanisms and monitoring technologies are needed to protect the ecological environment against external factors such as land development.

C. The vigorous development of high-tech industries has released various types of pollutants or chemical substances that are detrimental to the environment

From the present to 2035, the development of new technological applications will have satisfied the needs of people and industries but at the expense of the environment; specifically, new types of pollutants will be produced, such as fluorescent agents in clothing materials or flame retardants in electronic components, leading to serious environmental pollution. In addition, chemical substances in Taiwan are governed by law according to their purpose of use. Therefore, the integration and integrity of relevant laws should be continuously strengthened, and the management, including risk control and prevention, of chemical substances that are hazardous to the environment should be integrated across ministries to improve management efficiency.

(2) Response Strategies

A. Improve resource survey and monitoring technologies, integrate databases for more effective application, and develop a resilient ocean/sea environment

(A) Reinforce environmental information survey and monitoring capability, secure access to information on the soil environment of Taiwan and environmental changes, integrate it into national geographic information systems to share basic and core geographic information, which allows for faster circulation of environmental data and improves the integration and application of heterogeneous data, and use big data analytic to strengthen data analysis and application; construct a data integration platform to improve the efficiency of information circulation and facilitate data exchange and sharing.

(B) Establish a cross-ministerial strategic map of Taiwan's ocean/sea environment (such as observations of oceanic atmosphere, hydrology and terrain, geology, ecology, and radioactivity) to better understand the interactive effects of the ocean and atmosphere; develop a resilient ocean/sea environment to assist Taiwan in maintaining the continuous operation of critical systems such as offshore wind power and submarine cables to reduce risks of communication blackouts during disaster-induced power outages; and actively initiate research investigations on ocean energy, seabed minerals, and seawater hydrogen to identify alternative resources in the event that access to crucial resources is blocked.

B. Invest in ecological conservation and restoration technologies to build a biodiversity database for Taiwan

Promote S&T research on biodiversity, develop biotechnologies that are suitable for native species of Taiwan, invest in restoration and conservation methods for Taiwan's major ecosystems, evaluate nature ecology projects and their effectiveness, and strengthen ecological resource investigation, monitoring, conservation, and restoration; establish a biodiversity database and ecosystem health monitoring and assessment methods, conduct data management/protection, and establish a disclosure mechanism; investigate and keep abreast of changes in pesticide resistance, monitor the impact of environmental agents for environmental sanitation on non-target organisms and ecosystems, and adopt appropriate control methods.

C. Use cloud technologies to integrate environmental monitoring data, apply smart platforms for systematic environmental monitoring and management

(A) Use artificial intelligence, Internet of Everything, and cloud technologies to develop a digital environmental monitoring, emergency management, and monitoring management platform; strengthen climate disaster early warning system R&D and services; use monitoring data, reporting data, and simulation predictions to evaluate the range of impact of disasters or pollutants, which provides a basis for emergency evacuation, and combine the results with time-series monitoring data to optimize process or environmental management parameters and reduce environmental pollution and safety risks.

(B) Adopt smart technologies through inter-ministerial cooperation to effectively manage new pollutants and chemicals that harm the environment, and guide industries to adopt feasible alternative solutions; use methods such as monitoring, analysis, emission estimation, and model simulation to explore the interactive effects that climate change mitigation and air pollution control measures have on species that emit air pollutants and on emission levels, so as to promote mutually beneficial measures; establish a map of risks that civilians will face in their everyday life by compiling risk information from data platforms, such as environmental pollution (noise, air, water, ocean), ionizing radiation, crime hotspots, and frequency of accidental incidents in various areas of Taiwan, to help citizens from different areas to respond to risks more effectively and prevent risks or accidents.

4.5 A Democratic S&T System

Political polarization has been developing worldwide since 2018. The divergence of systems and values between different camps became increasingly prominent. Despite interdependence and division of labor, countries are still competing for technological breakthroughs to ensure their national security and development. Under such circumstances, Taiwan must establish strong asymmetrical combat capabilities in terms of military defense in order to be a trusted partner of democratic countries; play a central role in industries and technologies that are critical to national security; and be an active participant in international activities and helping other countries so that when we help ourselves, others will help us. Under current international trends, data governance is dominated by major countries such as the United States, European Union, and China; Taiwan needs to strike a balance within to achieve the goal of driving the general progress of the country with data.

To achieve the goals mentioned above, we must propose strategies for tackling the problems and challenges of four main issues: Dual-use technology, national security-related S&T plans, data governance and legal systems, and S&T cooperation among democratic countries.

4.5.1 Civil-Military Dual-Use Technology

(1) Problems and Challenges

A. There are not enough resources to invest in all critical technologies

Given the limited resources in Taiwan, we need to identify which projects should be developed and prioritized for tackling current problems and challenges. For example, because the geographic conditions of Taiwan are unchanged, S&T development should emphasize national defense in response to geopolitical changes to deploy plans for national defense technologies for 2035 and accordingly investigate key focuses that facilitate Taiwan's national defense development in the future.

B. New critical technologies threaten national security

Although critical technologies can be an advantage for Taiwan, we should pay attention to the strengths development of some countries and evaluate whether these strengths will become Taiwan's Achilles heel in the future battlefield or overall national security. In addition, several technologies can also cause harm during peacetime. For example, the US military believes that small drones may threaten national security because of secret agents, criminals, or improper operations. Therefore, under grey zone operations and hybrid threats, relevant problems should be further evaluated.

C. Public and private sectors are not adequately integrated

According to Taiwan national defense reports, achievements in recent years with respect to dual-use technology development mainly involve technology transfers between the National Chung-Shan Institute of Science and Technology and private corporations. Cooperation with powerful private S&T industries is mandatory to achieve results or assist each other for a stronger performance in frontier technologies.

(2) Response Strategies

A. Leverage civil-military dual-use technology cooperation platform to enhance autonomy in national defense technologies

(A) Leverage private resources and capabilities to develop a civil-military dual-use technology collaboration platform, promote industry–academia collaboration on dual-use technology, and ramp up research efforts on key technologies to improve the nation's capability to manufacture technologies locally; assist industries in obtaining international certifications, thereby facilitating the integration of national defense supply chains.

(B) Modify the original procurement, supply, and cooperation model, focusing particularly on developing collaboration models, to strengthen the input of private resources and capabilities so that Taiwan's powerful strengths in ICT can contribute to military operations; these efforts require stronger innovation capability in the public sector, so the government needs to join forces with small startup companies, in addition to large suppliers, and also streamline administrative procedures to improve efficiency.

(C) Keep in mind that the ICT industry (a strength of Taiwan), unmanned vehicles (that Taiwan is currently committed to developing), and space fields (in which Taiwan has a little foundation) are critical to the future of Taiwan and the establishment of a public–private cooperation model; accordingly, plan roadmap for the development of unmanned vehicle technologies and applications, and expand the deployment of unmanned vehicle (including air, water surface, underwater, and land) technologies and industries to combine the innovation and manufacturing technologies of industry, public, academic, and research sectors, while strengthening R&D subsidies, sandbox, industry–academic–research centers, and government procurement mechanisms to boost the development of the unmanned vehicle industry and enhance national security.

B. Take an inventory of and set priority order for technological development and international cooperation strategies

Under limited national resources, take a full inventory of and identify strengths and weaknesses with respect to key technologies and the priority of acquisition; evaluate the capability of Taiwan to independently develop relevant technologies and concentrate the limited resources on S&T developments over which Taiwan has an advantage, that have development potential, or is critical to Taiwan; promote public–private cooperation, strengthen interdisciplinary talent integration, and foster academic literacy and practical participation, among other capabilities;

strengthen incentives that motivate allies to cooperate with Taiwan on science and technology, particularly critical technologies that Taiwan possesses but other countries lack.

C. Improve public–private collaboration fact-checking mechanism to strengthen the government's ability to combat cognitive warfare

Develop whole-of-the-society approach to tackle challenges from the S&T advantages of hostile forces, as well as grey-zone conflicts and hybrid threats; join forces with private corporations to develop systems for countering weaponized drones; improve public–private collaboration fact-checking mechanism for threats from misinformation and information warfare, develop AI-oriented network and communication technologies for military and civilian use, and empower citizens to strengthen their media literacy, instant response to the infiltration of false information and weaponization of public opinion, and their will to defend democracy.

4.5.2 National Security-related S&T Plans (including Protection of Core/Critical Technologies)

(1) Problems and Challenges

A. S&T resources in relation to national security should be optimally allocated

Government agencies and the business sector should focus on R&D investments and pioneer technologies and actively expand the direction of development investments. With respect to government operations, the Executive Yuan launched the Plan of Non-Highly-Sensitive Defense Technology Promotion in 2019, using an inter-ministerial model in budget planning, coordination, and supervision matters. On an inter-ministerial coordination platform, the Ministry of National Defense, Ministry of Economic Affairs, and NSTC jointly established a National Defense Technology Development Promotion Committee, which is responsible for establishing national defense technology industrial development plans, conducting investigations on the production capacity of S&T industries, and carrying out jobs related to talent development and employment. The NSTC and Ministry of

National Defense jointly convene an Academic Cooperation Development Report meeting, while the Ministry of Economic Affairs and Ministry of National Defense jointly host an Industry Cooperation Development Report meeting. However, the Ministry of National Defense ceased the adoption of the Guidelines for Setting up a National Defense Technology Development Promotion Committee on February 28, 2020. In the future, the ministries can continue to optimize relevant mechanisms and task operations and deepen decisions concerning national security S&T policies, with reference to the United States' experience of establishing the National Science and Technology Council within the White House in 1993, or Japan's Council for Science, Technology and Innovation within the Cabinet Office.

B. The autonomy in national security-related S&T capabilities can be strengthened further

The government-funded science and technology research projects of national core security controls operations manual published by the S&T Working Group of NSTC encompasses six categories of technologies: agricultural technology, key manufacturing technology, aerospace and satellite technology, marine technology, advanced integrated circuit design and process technology, and key cybersecurity technology[34]. Nevertheless, relevant government departments must collaborate with each other on specific S&T development roadmaps and incentive measures, such as development subsidies and funding (technology) investments in relation to current military–civilian cooperation, industry–government–academia–research collaboration, and the Defense Industry Development Act. Such collaboration aims to motivate investments in advanced technology R&D and overcome predicaments facing the national defense industry (e.g., small market, low exports, low R&D investment intention), thereby promoting the autonomy of Taiwan in science and technology.

C. Governance for the security of national core technologies must have

[34]NSTC (2023), Safety Control Handbook for Government-Funded National Core S&T Research Projects, retrieved from: https://www.nstc.gov.tw/nstc/attachments/10632523-c3de-41c8-b0b6-ae1f1fd8fdce.

a stronger collaboration mechanism

Other countries are actively acquiring technologies from other countries through business investments and academic collaboration to tackle challenges in the development of critical technologies. For example, China has enforced military-civil fusion policies and launched the Thousand Talents Plan to do so. These situations highlight the urgency of establishing a sound S&T security governance for Taiwan. The security of Taiwan's science and technology is stipulated in the National Security Act, the Fundamental Science and Technology Act, the Trade Secrets Act, the Classified National Security Information Protection Act, and the National Intelligence Service Law Work Act. In June 2022, the Taiwan government amended the National Security Act and the Act Governing Relations between the People of the Taiwan Area and the Mainland Area. The former amendments imposed harsher punishment for economic espionage and act that infringe upon the trade secrets of any national core critical technology, and the latter amendments provided that individuals who had engaged or had engaged within the past three years in any business related to any national core critical technology must be subject to review for approval. With regard to the security mechanism of national defense industries, the Defense Industry Development Act also mandates the establishment of evaluation mechanisms and other mechanisms for strengthening personnel, facility, and information security control. However, ministries and committees involved in relevant mechanisms must strengthen both top–down and parallel coordination and cooperation efforts.

(2) Response Strategies

A. Strengthen the government's allocated role in national security-related S&T resource mechanisms

Deploy national security-related technologies by establishing an effective and comprehensive coordination mechanism that encompasses national security-related talents, resources, and budgets, including the Plan of Non-Highly-Sensitive Defense Technology

Promotion and highly-sensitive national security-related technologies; strengthen, through an inter-ministerial coordination platform, the National Defense Technology Development Promotion Committee, which is jointly established by the Ministry of National Defense, Ministry of Economic Affairs, and NSTC and is responsible for establishing national defense technology industrial development plans, conducting investigations on the production capacity of S&T industries, and carrying out jobs related to talent development and employment; reinforce views on national decision-making and implement the deployment of S&T development.

B. Invest resources to promote the development of autonomy in national security-related technologies

(A) Establish the capability to independently conduct and develop science and technology, continue to elevate the level of national security-related technology, and actively promote international cooperation and talent exchange to secure a place in global S&T supply chains; employ a comprehensive coordination system to develop a roadmap for national security-related S&T development, integrate the innovation capabilities of industries, government, academic, and research institutions, and invest S&T resources into projects that show development potentials such as aerospace and ICT industries; take advantage of opportunities to cultivate scientific research capability and foster interdisciplinary scientific researchers, thereby developing the nation's S&T autonomy and reinforcing the strengths of S&T industries.

(B) Develop smart national defense capability and develop such industry, strengthen artificial intelligence research and talent development, and integrate big data in the private sector, IoT, 5G technology, ICT, and manufacturing capacity through a dual-use technology cooperation mechanism to encourage industries to engage in development and expand applications, thus strengthening the autonomy of the national defense industry.

C. Establish a governance mechanism for the security of national

core/critical technologies

Establish a national core technology security governance mechanism that is integrated from top to bottom across ministries, is inclusive of civic/social participation, and meets international cooperation requirements; request scientific research institutions to implement internal management practices and comply with regulatory requirements to ensure that scientific research results are properly protected and that the protection of key technologies is supported by citizens; improve the hierarchical protection system of national core key technologies to reinforce the protection of Taiwanese industries and technologies, strive for transnational trusts in international S&T cooperation, boost the mature development of domestic S&T industries, bolster the competitive advantages of Taiwanese corporations, and safeguard the lifelines of Taiwan and its economy.

4.5.3 Data Governance Laws (including Knowledge on the Cybersecurity of S&T Industries)

(1) Problems and Challenges

A. Data governance policies need to be clarified with respect to general ideals and be aligned with international practices

The government should have a general idea or goal for data governance before proposing corresponding strategies and, at the same time, establish subject areas in which actions or resources should be prioritized or invested, and expound on the functions and roles of the government, industrial markets, and society. Furthermore, a data governance policy must place emphasis on international factors. Currently, data governance coupled with international political landscapes is dominated by major countries such as the United States, European Union, and China. China is essentially controlling the circulation of data and strictly restricting cross-border data transfer. Although the European Union and United States have disagreed on many digital-related issues, they have been working together against China in recent years. How to balance the cross-border circulation of data in the United States with EU's principle of personal data protection is also a topic that Taiwan must address. One of the keys to data sharing and utilization is data format and standards. Data standards are the basis of data circulation and exchange, and developing data standards will inevitably require international cooperation. However, the establishment and development of data standards in Taiwan are still underway, so no international cooperation measures have yet been established for data standards for main areas of application.

B. A government agency that oversees and a complete set of regulatory guidelines for the sharing and use of data is required

The implementation of data policies in Taiwan is based on the open data policy of the National Development Council. However, data governance has a considerably more comprehensive scope of application than open data, as it includes stipulations on the definition of data, data application, data monitoring, data rules, and data access for each stage of the data lifecycle, including data collection and generation, processing, analysis, storage, access, and reuse. Furthermore, an accountability system for organizations that collect and use data is required so that the sharing and use of data in both public and private sectors are protected by an appropriate legal system.

Current laws and regulations related to data governance are only focused the layers of data protection, rather than on approaches to alleviate data sharing barriers and to expound on data governance regulations. Existing barriers to data sharing include ambiguity in the right to access and distribution of generated data, lack of reliable data intermediary mechanism, unequal bargaining power of organizations, concerns about the misuse of data and lack of protection, and lack of legal basis for requesting information from organizations in the event of an emergency. In addition, the government holds numerous valuable information but lacks explicit rules and measures for compliance. Because of these barriers to data sharing, data generators, holders, or data subjects often feel uneasy about and are uninterested in sharing data and, therefore, they only use data internally within their organization. Consequently, these data are withheld by data holders and organizations or individuals in possession of these data are not willing to release more data for reuse.

C. Organizational data governance capability must be improved to maximize the benefit of data development

According to a survey report[35], the gap between understanding data and effectively translating data into useful information is primarily due to limited data literacy in the workplace. Because the pandemic accelerated digital transformation, cybersecurity risks grew increasingly more prominent than before. Diverse services have made information security and risk control a top priority for many companies. The demand for cybersecurity is outpacing available cybersecurity talents in the employment market.

Not all data providers (e.g., data producers, data holders, and data subjects) are capable of processing, analyzing, and applying data; most of them still must rely on data service providers (e.g., data intermediary services and data platforms) to fully utilize data and its value. Therefore, the vigorous development of data service providers has become the focus of the data-driven ecosystem; however, there are still numerous challenges in Taiwan's data service industry, including how to ensure data quality, rights and obligations in data transactions or exchange, and how to promote a reliable ecosystem of data intermediary services and ensure trust and fairness during data sharing activities. In short, the absence of a corresponding governance structure has created challenges in the development of the data service industry. Without a consensus, the industry cannot foresee a clear development prospect nor become a sturdy pillar for the implementation of data governance in the future.

(2) Response Strategies

A. Develop national-level data strategy policies and establish long-term visions and implementation strategies for the country

[35] Data Literacy Project (2022), Data Literacy: The Upskilling Evolution, URL: https://www.qlik.com/us/-/media/files/resource-library/global-us/direct/datasheets/ds-data-literacy-the-upskilling-evolution-en.pdf.

(A) Formulate a national-level data strategy policy detailing the objectives and strategies for each stage of implementation, and regularly roll out policy reviews and revisions, build a data governance-related system by disclosing the pathways and methods of implementations to achieve data governance goals, thereby realizing the development goals; select a central topic such as net zero, greening, education, and health care to serve as the area of focus in the development of stage-based data governance and effectively utilize the critical value of data in public governance and social development.

(B) Jointly promote data governance through organizational "empowerment", motivate government organizations, social organizations, or business organizations to engage in digital transformation, and cultivate relevant talents and improve organizational processes to strengthen data competency and implement data governance.

B. Encourage data governance practices that contribute toward the good of the society, and develop data governance best practice principles to facilitate the accumulation of practical experiences and approaches in the data-driven ecosystem

Encourage data governance practices that give priority to scientific research data and contribute toward the good of the society, and develop data governance best practice principles; take progressive steps in building a research data platform that encourages contributions to the government a certain percentage of research data generated from government-funded projects, and make research data accessible, interoperable, and reusable by constructing a mechanism that allows access to and reuse of research data, so as to avoid waste of research resources, to facilitate the reuse of results and data generated from government-funded research, and to contribute fully to Taiwanese nationals and social well-being.

C. Build a reliable data service governance model thereby boosting the vigorous development of data-driven ecosystem

(A) Take progressive steps in establishing principles with which data service providers should comply, and develop management mechanisms and policies that form a governance framework for provision of data services to strengthen confidence in the development of data-driven ecosystem.

(B) Create a mechanism and regulatory system for use of health data in accordance with Taiwan Constitutional Court 111-Hsien-Pan-13 so that health-related data can be used with peace of mind, thereby unleashing Taiwan's advantages over health data and building a biomedically resilient homeland that will become an international hub for precision medicine development and drive the vigorous development of a data-driven ecosystem.

(C) Establish AI data governance and management rules through reliable data governance services, provide high-quality data for AI development, create a data governance-based environment for the R&D and application of AI technology, and strengthen compliance mechanisms for data application to realize a trustworthy AI that governs data in adherence to the principles of fairness and explainability and to form a positive cycle that drives the overall development of AI.

4.5.4 S&T Cooperation Among Democratic Countries

(1) Problems and Challenges

A. Incentivize international communities to cooperate with Taiwan

Taiwan has so far been unable to join major international organizations or institutional arrangements such as the World Health Assembly (WHA), the International Civil Aviation Organization (ICAO), and the Regional Comprehensive Economic Partnership (RCEP). As for US-led international cooperation mechanisms, such as the Indo-Pacific Economic Framework for Prosperity (IPEF), Taiwan remains committed to vying for inclusion in this framework, which shows that even with similar values and concepts, Taiwan still needs to more actively create opportunities for cooperation with other countries under increasingly intense geopolitical confrontation.

B. Democratic countries reduce dependency on Taiwan through collaboration

Taiwan has considerable advantages and even an irreplaceable role in specific industries and technologies, specifically semiconductor and electronics industries. TSMC was regarded as a “sacred mountain that protects the nation”, with a global market share of 53.6% in June 2022[36]. Nevertheless, because the possibility of armed conflict or even war between Taiwan and mainland China cannot be ruled out, the United States and other democratic countries are attempting to reduce their dependence on Taiwanese industries in order to mitigate geopolitical risks. In other words, Taiwan’s irreplaceable position in certain industries is the reason why the United States hopes to reduce its dependence on Taiwan. On August 9, 2022, US President Biden signed into law the CHIPS and Science Act (CHIPS: Creating Helpful Incentives to Produce Semiconductors), which provides US$52.7 billion to fund infrastructure constructions for semiconductor manufacturers in the United States, and the rest is used to encourage new manufacturing and scientific research activities. One of the purposes of this Act is to reduce U.S. dependence on Taiwan and disperse risks. When promoting international S&T cooperation, Taiwan should also pay attention to the maintenance of its own advantages and interests.

C. Taiwan’s national defense industries are struggling to penetrate international markets

S&T cooperation with democratic countries is aimed at ensuring the security and prosperity of Taiwan. The development of local national defense industries is an integral part of this process. In this aspect, although some industrial and business sectors in Taiwan have technological advantages, they are unable to establish a global presence because the domestic market is too small for further development. To develop autonomous defense capabilities, Taiwan needs to help

[36]Chien-Chung Chang (2022), Top 10 global wafer foundry manufacturers report record-high revenues for 11 consecutive quarters, with TSMC dominating the industry, retrieved from: https://www.cna.com.tw/news/afe/202206200186.aspx.

relevant industries access the international market, thereby providing incentives for continuous R&D and investment. Given the prospect of a "divide-and-conquer" tactic in the technological war between US and China, a prerequisite for cooperation on S&T will be integrating with the standards adopted by advanced democratic countries.

(2) Response Strategies

A. Establish an S&T security governance mechanism that conforms to international regulations, accentuate strengths in different fields of scientific research, and creates opportunities for democratic S&T cooperation

(A) Reinforce active and passive conditions for participation in international cooperation, with active conditions highlighting strengths in scientific research and passive conditions being institutional regulations for passage to democratic countries; develop an S&T security governance mechanism that conforms to international regulations to facilitate participation in the S&T initiatives and alliances of democratic countries.

(B) Adopt a program similar to the U.S. Cybersecurity Maturity Model Certification (CMMC) program, which requires defense contractors/subcontractors to obtain cybersecurity certification and is expected to be applied to other industries and countries; prepare for expansion of this application by promoting the standardization of digital or S&T products, security certification and supervision systems.

(C) Appropriately examine and revise the procedures for determining "national core key technologies" and compliance regulations, and moderately incorporate public opinions, so as to ensure national security and industries' international competitiveness.

(D) Highlight Taiwan's achievements with respect to pandemic prevention, public health, and defense against cyberattacks and misinformation from China, and take advantage of the international trust that Taiwan has gained, through joining the U.S. Clean Network or signing the US-Taiwan Initiative on 21st-Century Trade, to actively participate in the S&T initiatives and alliances of democratic countries, thereby expanding international cooperation on S&T activities.

(E) Enforce the protection of critical technologies, apply science and technology to consolidate and deepen democracy, and launch technology-driven diplomacy by strengthening laws and civil involvement, and build strategies for developing critical technologies and enhancing national security, thereby infusing S&T into Taiwan's geostrategies.

B. Promote S&T diplomacy and provide incentives and mechanisms that facilitate the two-way flow of scientific research talents

(A) Build an environment that is conducive to transnational S&T cooperation to increase the intention of other countries to cooperate with Taiwan.

(B) First, take an inventory of the industrial structures and technological capabilities of core strategic industries, draw up a development blueprint, and in turn clarify strengths and which technologies are still lacking.

(C) Second, retain S&T advantages in key areas so that an irreplaceable role in supply chains makes it conducive for other countries to cooperate with Taiwan.

(D) Third, leverage S&T diplomacy to fortify international ties, such as establishing research organizations in democratic countries, encouraging Taiwanese scholars to engage in overseas cooperation and exchange, and reviewing immigration and employment policies to build a friendly living environment that attracts foreign highly skilled professionals to work in Taiwan.

C. Maintain the technological advantages of strategic industries and build the strength and environment to participate in international cooperation

Establish a military aircraft airworthiness certification system, and join forces with corporate entities to develop verification specifications for enhancing their ability to verify industries; and actively establish internationally recognized UAV classification, certification, and management systems for UAV industry, which has potential and is suitable for Taiwan's development.

4.6 Overarching Strategies

4.6.1 Scientific Research System

Build an inclusive scientific research system that ensures resource integration to help reduce social class and gender differences, thereby realizing a fair, just, and gender-friendly life in society; implement inter-ministerial communication as the core framework for policy implementation, incorporate industrial development into policy planning, and establish a positive cycle of scientific research and development; overcome policy gaps through ministerial cooperation, coordinate the effective allocation of national and private resources, and establish consensus and resource input for the advanced deployment of frontier technologies. This aspect encompasses the following three strategies:

(1) An Innovative Scientific Research System Governance Model

A. Build a scientific research environment in which gender equality, diversity, and inclusiveness are advocated

(A) Enhance female empowerment in S&T to support female engagement in STEM (science, technology, engineering, math) learning and research; establish a female role model in scientific research to strengthen women's sense of belonging in this field and effectively increase the number of women in the STEM field, thus boosting Taiwan's technological development and competitiveness.

(B) Initiate dialogs and adopt civic participation mechanisms to address major societal concerns; collect ideas from the public on the application of technology to solve societal problems, and modify evaluation indicators through subsidy programs for S&T projects whose social benefits outweigh economic benefits to encourage investments from the business sector.

(C) Allocate a fixed amount of S&T budgets to address unmet societal needs, such as health and care, cultural equality, closing the education gap, improving resource and energy self-sufficiency, and large-scale disaster response mechanisms, and to develop inclusive technologies for research and development.

B. Strengthen ministerial collaboration on co-creating a flexible system that increases the efficiency of scientific research

Establish an inter-ministerial S&T policy communication platform, study and draft plans on S&T strategies from a nation's macro perspective, fortify the relationship that national S&T policies have with society, economy, industry, and the environment, properly integrate ministerial tasks, discuss and plan national S&T strategies, integrate resources, coordinate interdisciplinary S&T project objectives, and discuss relevant laws and regulations; integrate technologies as a whole across ministries to address various complex issues, establish an inter-ministerial, top–down integration model, and propose innovative and agile action plans.

(2) Deepen the fundamental structure of the scientific research system

A. Exploit public scientific research institutions to support the development of frontier technologies

Use a national-level scientific research platform to support early-stage S&T development, adopt opinions from industry, academia, and research sectors at the project conceptualization stage, derive research ideas from technological bottlenecks and demands of current industries, strengthen the application of technological results through a partnership with industry, academia, and research institutions, and develop industry, government, academia, and research sectors into a scientific research industry cluster to form a regional innovation hub.

B. Adopt data governance guidelines for cementing the foundation of industrial applications

Formulate a national-level data strategy policy, with data at the core of S&T development, and detail the objectives of data accessibility, utilization, and supervision, approaches to realize such objectives, and methods of implementation; encourage contributing to the government a certain percentage of research data generated from government-funded projects, and adopt a mechanism that allows access to and reuse of data in order to make national scientific research results and data reusable for social contribution and the well-being of society.

C. Deepen interdisciplinary dialog and communication for the stronger industry–academia–research collaboration

Strengthen links between S&T policy and the needs of industries and society to realize the core concept of inclusive technology; place emphasis on the dialog of various stakeholders, such as implementing civic engagement and inspiring deeper communication and exchange among industry associations to improve key technology development strategies; launch a variety of public–private cooperation models and invite private business sectors to join so that an agile team and trial-and-error for the integration of public and private resources can be promptly achieved to promote the technological transformation of Taiwan and implement S&T innovation.

(3) Properly allocate national resources and translate national scientific research into practice

A. Plan long-term scientific research policy guidelines and improve performance evaluation for innovative scientific research projects

(A) Establish a topic selection and competency evaluation mechanism based on rigorous evidence-based data analysis to identify frontier technologies that best meet the interests of national development in the next 10–15 years and ensure that resources are appropriately allocated to Taiwan's mid/long-term development of key technologies.

(B) Properly plan long-term guidelines for policies to drive the long-term development of various technologies and industries; for example, allocate a portion of cross-ministry mid/long-term S&T budgets, adopt a goal-oriented performance evaluation based on target achievement in conjunction with an exit mechanism to improve project performance evaluation processes.

B. Invest in the research and development of long-term high-value scientific research fields

Invest in, instead of funding, R&D projects and incorporate a profit-sharing mechanism, thereby stabilizing the country's mid/long-term scientific R&D resources; increase incentives that will attract friendly and credible international teams or funds to participate in the research and development of high-value technologies that are strategically needed in Taiwan; and attract domestic and foreign investments in the commercialization and application of high-value scientific research results.

4.6.2 Innovation Capability and Ecosystem of Innovation

Rapid changes in the global political and economic environment have intensified de-globalization. In the future, we must build on Taiwan's competitive advantages, give priority to domestic production, accumulate scientific research and innovation capabilities, and develop short-chain advantages in specific technologies. Furthermore, we must adopt appropriate technologies through a people-centered approach to address the needs of society, economy, and environment, establish an innovation ecosystem that integrates resources flexibly, strengthen the local integration of science parks, accelerate digital transformation and net zero transition, and promote industrial diversification. This aspect encompasses the following three strategies:

(1) Sound Industry Supply Chain

A. Foster next-generation industries by tapping into Taiwan's scientific research advantages

Align the technological capability of industry, academia, and research institutions in Taiwan with the development needs of Taiwan and other countries, take an inventory of industries to identify S&T projects that can be developed in the future, draw up S&T development roadmap, and foster new industries that demonstrate development potential through long-term flagship projects or invest in industrial planning research that paves the way to innovation and R&D, which drives the sprouting of next-generation technologies and facilitates the return of new technology industries to the market; build a complete ecosystem comprising satellites, ground stations, rockets, and relevant services, develop core satellite and next-generation communication technologies that are suitable for Taiwan, and support industries to build mass production and system integration capabilities.

B. Connect to the world's innovation capability to make Taiwan's supply chains more resilient

(A) Shift from single-point entry to nationwide expansion, urge major international manufacturers to establish their R&D base and digital platforms, conduct R&D, and train talents in Taiwan; guide upstream and downstream suppliers in Taiwan to connect their platforms or form a network of systems, with Taiwan as the test base and the starting point of supply chain integration so as to transform Taiwan into an integrated cluster of advanced manufacturing supply chains representing democratic countries.

(B) Establish an internationally recognized base that develops the practical application of next-generation strategic technologies and provides a world-class infrastructure where the resources of key industries are leveraged; this base will, in turn, attract international R&D professionals to work in Taiwan and help develop semiconductors, quantum technologies, and value-added applications, thereby increasing the autonomy and international status of Taiwan in the area of next-generation strategic technology.

C. Optimize interdisciplinary collaboration mechanism to maximize the synergy of resource integration

Through interdisciplinary cooperation mechanisms and platforms, strengthen the horizontal integration of public and private sectors, streamline administrative procedures to enhance efficiency, and promote cooperation between SMEs and startups; for example, establish demonstration cases by referring to U.S. data sharing platforms and by implementing pilot projects, to demonstrate both the security and benefits of sharing data and thus boost public confidence in open data.

(2) Stabilize S&T budgets to meet social needs

A. Invest in expenditures on long-term scientific research to prepare for the country's needs in the future

(A) Make yearly investments that aim to ensure that digital, biomedical, and net-zero transition applications are in adherence to the principles of fairness and impartiality for socioeconomic development; specifically, invest in the expansion and deepening of science, technology, and society (STS) studies, cultivate a pool of intergenerational researchers, and establish a STS research center that connects the research networks of various universities, conducts holistic research on the ethical impact of S&T applications, on the formulation of laws and regulations, on a sound ecosystem for industrial development, on social, economic, and political impact assessments, and on the establishment of a social security system, and proposes evidence-based policy recommendations that are innovative and substantively beneficial.

(B) Allocate a fixed scientific research budget in line with the short/mid/long-term R&D objectives as outlined in the Instructions on the Development of National Defense Technology published by the Ministry of National Defense, and select advanced key technologies for development such as aerospace vehicles, precision guidance, radar, communications, underwater intelligence gathering, and information security protection, and seize opportunities that arise when the United States, Japan, and the European Union strengthen their national security technologies.

(C) Discuss on a minimal amount of funds to mobilize each member of the society to participate in determining the direction of the nation's S&T development, which will reveal the unmet needs of the society and key technologies required for R&D, collect ideas from the public on the application of technology to solve societal problems, and adopt civic participation mechanism to address major societal concerns, such as using technology to build a local aging service system that provides one-to-many care services, instead of one-to-one, to effectively utilize the resources of care service providers.

B. Increase citizens' participation willingness and improve public–private partnerships

Determine the needs of society through civic participation, introduce public–private partnership (PPP) programs that focus on the S&T development of Taiwan, and encourage industry-leading organizations such as industry representatives or academic and research institutions to participate in these program; for example, set up a transformation fund or provide economic incentives to align the energy transition process with the principles of fairness and justice (such as assisting SMEs to purchase renewable energy certificates at a reasonable price), and engage in effective communication to help reach consensus and promote fair energy transition; strengthen incentives for GHG reduction, increase industries' participation willingness, and obtain social consensus and support to achieve net zero transition by 2050; promote regional net zero transition alliances, establish PPPs, and encourage information sharing to inspire and promote public awareness of threats, challenges, and responses in relation to climate change and environmental pollution.

(3) Accelerate science park transformation

A. Fulfill the role of an innovation hub to spearhead industry upgrade and transformation

(A) Assess manpower and skills required by new next-generation technology industries and adjust them dynamically to the development progress of new technology industries to optimize the parks' ecosystem of innovation and co-create total solutions for industrial, urban, and social innovation.

(B) Current advantages coupled with future trends, develop next-generation science parks and spur other types of science parks to collaborate with promoting frontier industries, thereby creating an ecosystem of innovation that drives social changes.

B. Build a green and sustainable ecosystem in line with global net zero transition trends

Align with the goal of achieving net zero emissions by 2050 and develop a distributed green energy digital management system that places park-level energy storage and renewable energy systems at the core to build a virtual power plant in the science park and ensure uninterrupted production in key S&T industries.

4.6.3 Talent Development

In a world of geopolitical confrontations, net zero emissions and environmental sustainability in addition to population aging, dwindling birth rate, and demand for highly skilled professionals have become a global trend. In light of these risks, innovation talents must be cultivated to meet the demands of S&T industries, paving the way for interdisciplinary and integration, and build a pool of high-caliber professionals. Talented workers who will have a vital role to play in the country's economic transformation must be fostered by introducing different learning and training channels through public–private partnerships. The deployment of frontier technology capabilities and talent development through international cooperation and talent recruitment is also key to increasing the autonomy and international status of Taiwan in the area of next-generation strategic technology. This aspect encompasses the following three strategies:

(1) Empower innovation for interdisciplinary talent development

A. Use digital IT tools to bridge education gaps

(A) Provide education programs that are personalized to students' backgrounds such as ethnicity, gender, generation, and learning ability; through these programs, students can personalize or tailor their learning to their learning conditions and characteristics by using digital instructional materials on digital devices, while teachers can provide assistance and guidance according to the students' learning results.

(B) Provide access to educational resources through digital learning methods, such as individual learning support systems for students and Massive Open Online Courses (MOOC), to provide distance learning programs and bridge education gaps.

B. Cultivate scientific research capability and foster talented grassroots scientific researchers to strengthen interdisciplinary talent integration

Enrich scientific research capabilities through large-scale galaxy projects and academic and research training and by leveraging world-class talents; grow the talent pool needed for the S&T development of Taiwan and strengthen interdisciplinary talent integration by fostering talented grassroots scientific researchers with advanced degrees in new technologies, and motivating young students to engage in basic scientific research and technological R&D innovation; for example, cultivate talented workers required for the development of S&T fields in Taiwan such as quantum, space, satellite, next-generation communication, digital transformation, energy transition, and net zero transition.

C. Improve the wisdom of the crowd through civic technologies

Build a social innovation observation platform, which uses civic technology to collect community plans and promote progress; and integrate real-time data to provide citizens with access to resources and data, which will improve their information literacy, particularly with respect to various ICT and appropriate technologies while also fostering the data application capability of civic groups across Taiwan so that digitally competent members can apply digital and data technology to diagnose community needs and use appropriate technology for the benefit of the general public.

(2) Invest in flexible and diverse human capital through public–private collaboration

A. Set up education and training platforms to sustain the value of talented professionals

Set up digital education, vocational training, and lifelong training platforms through public–private collaboration, integrate the platforms with the demands of relevant industries, provide employment transition avenues, sustain the value of talented professionals, and improve professional competency and productivity through training and skills certification.

B. Establish an international talent training base to facilitate the country's industrial transformation

Examine Taiwan's industrial structure, support the cultivation of technology talents in the business sector, and urge major international manufacturers to establish their R&D base and digital platforms, conduct R&D, and train talents in Taiwan; and combine the S&T strengths of Taiwan and utilize higher education resources in Taiwan to build a key talent pool for Taiwan that facilitates the industry economic transformation of emerging countries.

(3) Ramp up efforts in international cooperation and talent recruitment/retention

A. Engage in strategic international cooperation on scientific research and encourage knowledge exchange with world-class talents

Participate and invest in new S&T R&D projects through strategic international cooperation with reliable partners, and provide a world-class infrastructure that attracts first-rate talents to share experiences and exchange professional knowledge, thereby enhancing the capability of Taiwan to research and develop new technologies.

B. Build an overseas talent service platform to create a sound environment and talent recruitment mechanism

Establish an overseas talent service platform, create job opportunities in collaboration with domestic industries, form a strong force of attraction and connection with talents, and offer employment and living assistance while improving the living and child-rearing environment in Taiwan and perfecting talent recruitment and retention mechanisms.

4.6.4 International Cooperation

In the midst of US-China competition and geopolitical risks, the government of Taiwan must take an inventory of Taiwan's strengths in the fields of science and technology, adopt international laws and standards, forge long-term ties with reliable international allies, and improve the autonomy of Taiwan in critical energy resources, to assuage the impact of international resource supply disruptions. This aspect encompasses the following three strategies:

(1) Actively link to international markets and resources

A. Tap into strengths in the fields of science and technology and seek opportunities for strategic international cooperation on scientific research

Continue to monitor international economic cooperation initiatives such as the Indo-Pacific Economic Framework for Prosperity (IPEF) or Chip 4 alliance with the United States, Japan, and South Korea, draw on this foundation to leverage resources for deeper development, and seize hold of worldwide opportunities through strategic international cooperation on scientific research with reliable partners.

B. Attract foreign investments in Taiwan to help startups establish a global presence

Subsidize a portion or amount of expenditure on R&D or equity funds to promote joint R&D efforts by transnational companies and Taiwanese startups, cultivate international markets, and attract international venture capital to participate in Taiwan's early-stage fundraising for startups, thereby helping startups in Taiwan to penetrate overseas markets.

(2) Develop national-level S&T international cooperation strategies

A. Build an inter-ministerial S&T international cooperation platform for proper resource allocation

Establish an inter-ministerial collaboration platform for international cooperation on science and technology, calibrate the goals of ministerial strategies for international cooperation and integrate ministerial resources, select key research topics for international cooperation according to Taiwan's mid/long-term development strategy, and allocate resources accordingly.

B. Nurture autonomy in science and technology to reduce geopolitical risks

Assess the importance of critical technologies and rank them in order of priority, strengthen, through international cooperation, areas of science and technology that Taiwan is more capable of developing, and promote private investment in development to acquire and nurture basic capability in achieving S&T autonomy.

(3) Adopt international laws and standards

A. Help new industries adopt international standards to expand industrial and scientific research development

Help new technology industries adopt international standards so as to transform Taiwan into Asia's central base for testing new technological products and concurrently build a foundation for entry into global security supply chains through the standardization of digital or S&T products or adoption of security certification and supervision systems.

B. Adopt international data standards to elevate economic security and stability

(A) Promote the adoption of international data standards in Taiwan to facilitate interdisciplinary data exchange and integration for data analysis and application.

(B) Review Taiwan's data governance to comb through policy options related to cross-border data transfer, clarify trade-offs involving the interests of Taiwan based on aspects of the democratic system, social development, and economic trade, ensure that Taiwan's relevant policy options are aligned with allies, and develop relevant policies that give priority to the interests of Taiwan.

4.6.5 Regulatory Framework

With the rapid development of technological innovations, the traditional regulatory framework became a hindrance to rapid breakthroughs in science and technology; therefore, an S&T regulatory framework for the 2035 technology vision must be inclusive, flexible, and secure. For this reason, we must expand civic engagement and increase social acceptance and public support toward S&T development. Meanwhile, existing laws and regulations must be reviewed, revised, and coupled with supporting measures to achieve a just transition. In addition, an overarching data legal system with a data economy at the core must be constructed to accelerate S&T development through open data and data sharing.

(1) Revise existing laws and regulations to alleviate the impact of new technologies

A. Promote supporting measures for existing laws to drive industry upgrades and transformation

Align regulatory amendments with the net zero goal of “waste decoupling” to create new value from wastes; implement supporting measures for applicable laws such as the Renewable Energy Development Act and the Electricity Act to boost the development of domestic energy storage industries; and formulate regulations and standards for the transportation and storage of hydrogen and ammonia energy.

B. Make laws and regulations flexible so as to encourage the adoption of new S&T applications

Review the effectiveness of labor, economy, and S&T related laws and regulations from a new perspective to consider the social impact of new technologies, and amend these laws and regulations as needed, while making industries more resilient to new technologies to mitigate developmental risks, such as risks arising from the real-life adoption of innovative service models derived from innovative technologies.

(2) Build a regulatory framework for innovative technologies

A. Legislate data governance to provide guidance on social transition

(A) Legislate data governance to build trust, gain the trust of the society, and promote discussion and consensus in the society.

(B) Alleviate data sharing barriers through laws and regulations, including clarifying the right to access and distribute generated data, balancing the bargaining power and competitiveness of organizations, giving organizations certain legal rights to data in which they have a business interest, and providing a legal basis for requesting information from organizations in the event of an emergency.

(C) Stipulate clear rules and procedural measures on the use of data generated from scientific research projects so that more governmental data and scientific research data can be reused under effective protection measures.

B. Promote data empowerment through legislation to unlock the value of data

Engineer data-empowered legal governance including digital financial technologies and smart medical data, and relax data usage restrictions through an overarching data governance regulatory framework to unlock the value of data and develop more innovation applications.

Chapter 5 Conclusion

To fulfil our Vision 2035 for science and technology development — forward-looking innovation, democracy and inclusiveness, and resilience and sustainability, we must make the most of the power of technology to help overcome challenges and accomplish the comprehensive transformation of Taiwan's economy, society, environment, and politics. In addition to continuing investments to maintain our advantage in certain technologies, we must also preemptively prepare for revolutionary technologies that may reshape the future, and solidify the foundation that Taiwan has in science and technology to drive economic transformation. We must value the importance of appropriate technologies to address the needs of people, thereby ensuring a just transition for the society of Taiwan. Meanwhile, active investment in environmental technologies for sustainable development is key to transitioning toward net zero emissions by 2050, and we must also speed up the development of national security technologies to safeguard and consolidate democracy.

Ten general goals have been set for this White Paper on Science and Technology: 1) Promote gender equality, inclusive technology, and Appropriate Technology; 2) Invest in basic scientific research, and promote R&D of technologies in response to the needs of society; 3) Develop cutting-edge strategic technologies and an independent national defense industry; 4) Build an open, secure, and trustworthy data governance system; 5) Accelerate digital transformation and net-zero transition of all industries; 6) Set up, maintain, operate, and develop infrastructures for a resilient society; 7) Promote technological innovation and transformation of software and service industries; 8) Develop advanced manufacturing hubs and next-generation manufacturing industries; 9) Create a comprehensive diplomatic strategy that is driven by democracy and technology; and 10) Promote open and innovative talent development and vocational training. To achieve these goals, strategies have been described in previous chapters under a STEEP (Social, Technological, Economic, Environmental, and Political) framework. These strategies are summarized below.

1. Social aspect

To demonstrate the forward-thinking value of technology through social science research: to create a friendly environment for the development of all ethnic groups; to provide each person with the opportunity to learn and acquire skills; to promote a flexible, diverse, and co-participant educational system for capability nourishment; and to safeguard national security. By analyzing and managing the needs of the general public, we shall engage in multifaceted institutional innovation to achieve cultural equality and transition toward an inclusive, just society where costs and burdens are properly shared.

2. Scientific research (technological aspect)

Taiwan must strengthen its independent R&D capability in critical technologies such as next-generation semiconductors, precision medicine, and quantum technology; translate its strengths in satellite and next-generation communication technologies into advantages that will propel its advancement into international markets; and accelerate the development of new energy technologies that suit the local environment of Taiwan.

3. Economic aspect

Taiwan must enhance the resilience of its industries, improve economic innovation capability, promote digital transformation and net zero transition in science parks to prepare for the global shift toward local short-chain supplies, and boost demands for local urban/rural development. In the meantime, we shall develop a data-driven economy and trustworthy technology that serves as the foundation for digital and virtual economy development. In addition, we shall invest in the development of net zero technologies to respond to global demand for emissions reduction due to reinforced control of greenhouse gas emissions.

4. Environmental aspect

To tackle challenges from climate change, green supply chain requirements, and bottlenecks in the supply of key energy resources, Taiwan must strengthen the deployment of decarbonization technologies, promote the recycling and reuse of energy resources, leverage its advantage in ICT and digital technology, fortify climate governance, and improve its disaster prevention and mitigation capability, thereby constructing a robust, reliable, and affordable energy supply system.

5. Political and strategic aspect

Taiwan must establish strong capabilities for asymmetrical warfare in terms of military defense in order to be a trusted partner of democratic countries; therefore, industries and technologies that are critical to national security must play a central role. Meanwhile, Taiwan should actively participate in international activities and adopt the data governance models and standards widely adopted in other democratic countries and allies, thereby forging international relations in which others will help us when we help ourselves.

In addition, five overarching strategies are adopted for cementing the foundation for the science and technology development of Taiwan:

1. R&D system for science and technology development

Taiwan must build a scientific research system that is able to effectively mobilize scientific research potentials in the private sector, promote inter-ministerial cooperation, enhance data analysis capability and information transparency, encourage civic and industry participation in S&T development, and establish consensus and resource inputs for advanced and innovative technologies with local characteristics and advantages of Taiwan to promote the development of net zero industries, energy technologies, and quantum technology.

2. Innovation capability and ecosystem

Taiwan must create an ecosystem of open innovation to boost its innovation capacity for S&T development, prioritize domestic production, and develop short-chain advantages in specific technologies. Meanwhile, Taiwan shall adopt appropriate technologies through a people-centered approach to alleviate application bottlenecks, establish an innovation ecosystem that integrates resources flexibly, strengthen the individual uniqueness of science parks, and build an ecosystem of circular economy in the science parks and promote industrial diversification to build a technologically empowered industrial environment.

3. Talent development

Taiwan must cultivate interdisciplinary talents across different science and technology fields as a long-term S&T development strategy, extend its S&T strengths to new technology fields to grasp opportunities for transformation, and in doing so, strengthen the competencies of diverse and flexible talents, enhance technological cooperation with international communities with limited human resources, and create a competitive environment that will also attract international talents.

4. International cooperation

Taiwan must initiate multifaceted cooperation with international entities to maintain advantages and autonomy in scientific research; review its strengths in certain fields of science and technology and adopt international laws/regulations and standards with due consideration to US–China competition and geopolitical risks; forge long-term ties with reliable international allies; and increase the autonomy of Taiwan in critical energy resources to mitigate the impact of international resource supply disruptions and gain access to international markets and resources to make Taiwan stronger.

5. Regulatory framework

Taiwan must establish a regulatory framework that is flexible and adaptable to innovative technologies, review and revise existing laws and regulations and couple them with supporting measures, develop a comprehensive data legal system with the data economy at its core, and promote open science through open data and data sharing. In addition, Taiwan must enhance the competence of civil servants so that the development and application of science and technology will be free from the limitations of existing regulatory frameworks, thereby unlocking infinite possibilities.

As we embark on this journey of S&T development, we need to build an open society to support innovation; maintain a stable democratic system to achieve inclusiveness; promote interdisciplinary integration to realize environmental sustainability; use forward thinking to deploy technology; and lead the continuous improvement of Taiwan. In the future, the government will use the current issue of White Paper on Science and Technology as the basis to integrate and properly allocate resources, put each strategy into practice through inter-ministerial collaboration, spearhead S&T development, overcome challenges, and adopt technology as the driving force of Taiwan's profound transformation to realize an ideal life in which national security is ensured, a safe society is fostered, and citizens can live with peace of mind, thereby steering the country toward a future of forward-looking innovations, democracy and inclusiveness, and resilience and sustainability.

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