

## Part 1 Research Capacity of Japan – Realization of a Science and Technology Nation –

Research Capacity of Japan – Realization of a Science and Technology Nation –	2
Chapter 1 Japan's Current State of Research Capacity and the Challenges Faced in Research	4
Nobel Prizes Awarded to Japanese Nationals	5
Dr. Syukuro Manabe's 2021 Nobel Prize in Physics	6
Section 1 Paper Index	7
1 World Ranking in Number of Papers	7
2 Changes in the Number of Papers and Number of Adjusted Top 10% Papers	9
3 Changes in the Number of Papers by Type of Organization	10
4 Number of Papers and Number of Adjusted Top 10% Papers by Sector and University Group	11
5 Factor Analysis for Number of Papers	12
6 Comparison of the Number of Papers of Japanese, English and German Universities	13
Section 2 Ratio of Time Spent on Research by Researchers	14
1 Ratio of Time Spent on Research	14
2 Number of Research Hours in Annual Total Working Hours	16
3 Number and Share of Research Hours by Age Group	17
4 Constraints in Improving Research Performance	18
5 Specific Constraints in terms of Research Time and Research Funds	19
Section 3 Research Personnel	20
1 Number of Researchers Taking into Account the Ratio of Time Spent on Research	20
2 Number of Researchers by Field at National Universities, etc.	23
3 Percentage of Full-time University faculty members by Age Group	24
4 Percentage of Female Researchers	25
5 Number of Students Enrolled in the Doctor's Course	26
6 Number of Doctoral Degree Recipients per Population	27
7 Number of Research Assistants	28
Section 4 Research and Development Expenditures	29
1 Changes in the Ratio of Total R&D Expenditures to GDP	29
2 Changes in the Ratio of Government-Funded Research Expenditure to GDP in Major Countries	30
3 Changes in the Ratio of Governments Budget Appropriations for Science and Technology to GDP in Selected Countries	31
4 Changes in R&D Expenditures	33
5 Research Expenditure per Full-time Researchers in University Sector	34
Section 5 International Brain Circulation	35
1 Domestic Papers and Internationally Co-authored Papers in the Number of Papers and Number of Adjusted Top 10% Papers in Major Countries	35
2 Researchers Dispatched Abroad	38


3	Ratio of Researchers Dispatched Abroad (Mid-to-Long-Term) to Researchers Enrolled at Research Institutions	39
4	Changes in Doctoral Degree Recipients in the U.S.	40
Section 6	Patents, Technology Trade, and Cooperation between Industry and Academia	41
1	Number of Patent Families	41
2	Number of Papers Cited in Patent Families	42
3	Changes in Industrial Trade Volume in Major Countries	43
4	Joint Research Projects between Universities and the Private Enterprises	44
5	Number of Unicorn Enterprises	45
<b>Chapter 2 Science, Technology, and Innovation Policies of Japan</b>		<b>46</b>
Section 1	Basic Act on Science, Technology and Innovation and Science, Technology, and Innovation Basic Plan	46
1	Basic Act on Science, Technology and Innovation	46
2	Science, Technology, and Innovation Basic Plan	46
3	Government R&D Investment	48
Section 2	Review of Major Policies	50
1	Creation of Incorporated Administrative Agencies and National Research and Development Agency System, and Corporatization of National Universities	50
2	Promotion of Dual Support System	50
3	Grants-in-Aid for Scientific Research	53
4	Strategic Basic Research Programs	55
5	World Premier International Research Center Initiative (WPI)	56
6	Future Issues	57
<b>Chapter 3 Human Resource Development and Establishment of Research Environment to Support Research Capacity</b>		<b>58</b>
Section 1	New Projects for Strengthening Research Capacity of Universities	58
1	Establishment of University Endowment Fund	58
2	Comprehensive Promotion Package for Regional Core and Distinctive Research Universities	60
Section 2	Enhancing of Measures Related to Human Resource Development to Support Research Capacity	61
1	Comprehensive Package to Strengthen Research Capacity and Support Young Researchers	61
2	Improvement of Treatment of Doctoral Students and Expansion of Career Paths	63
3	Policy Package regarding Education and Human Resource Development toward the Realization of Society 5.0	64
4	Fostering and Promotion of Active Participation of Female Researchers Playing Leading Roles in Science, Technology, and Innovation	65
5	Fostering, Supporting, and Securing Management Personnel such as URAs and Technical Staff	72
Section 3	Strengthen Measures to Establish Research Environments	74
1	Promotion of Research DX	74

2	Shared Use of Research Equipment	75
3	Establishment of Large Research Facilities	79
Section 4	Specific Measures for the Strategic Promotion of International Development of Science and Technology	81
1	Strategic Promotion of the International Development of Science and Technology	81
2	Promote International Student Exchange and International Exchange at Universities, etc.	82
<b>Chapter 4</b>	<b>Social Implementation of “Knowledge” for Innovation Creation</b>	<b>85</b>
Section 1	Initiatives to Implement the “Knowledge” Gained from Research into Society and Thereby Create Innovations	85
1	Promotion of Research and Development and Social Implementation to Solve Social Issues	85
2	Promotion of R&D Projects Aimed at Commercialization, and Corporate Initiatives	90
Section 2	Initiatives to overcome novel coronavirus infections	99
1	Response to COVID-19	99
2	Medical Device Developed in Japan Continues to Save Lives of the COVID-19 Patients Worldwide	101
3	Development of Technology to Overcome COVID-19	103
Section 3	Economic Security	106
1	New Think-Tank Functions for Safety and Security	106
2	Key and Advanced Technology R&D through Cross Community Collaboration Program (K Program)	106
3	Act on the Promotion of Ensuring Security through Integrated Implementation of Economic Measures (Economic Security Promotion Bill)	106
Section 4	Status of Science, Technology and Innovation Policies Utilizing Convergence Knowledge (So-Go-Chi) - Reasons for the Need for “Convergence Knowledge (So-Go-Chi)” and Utilization of Convergence Knowledge(So-Go-Chi) to Solve Social Issues -	108
1	Why Is It Now Necessary to Examine the Convergence Knowledge(So-Go-Chi)?	108
2	Examples of Initiatives to Solve Social Challenges through Fusion of “Knowledge”	110

## Part 2 Measures Implemented to Promote Science, Technology and Innovation Creation

<b>Chapter 1</b>	<b>Development of Science, Technology and Innovation</b>	<b>114</b>
Section 1	The Science, Technology, and Innovation Basic Plan	114
Section 2	Council for Science, Technology and Innovation	117
1	Major Endeavors of CSTI in FY2021	118
2	Strategic Prioritization in the Science and Technology-related Budget	118
3	R&D Evaluation of Projects of National Importance	123
4	Major Deliberations at Expert Panels	123
Section 3	Integrated Innovation Strategy	124

Section 4 Revitalizing the Science, Technology and Innovation Administrative Structure and Flow of Funds	125
1 Administrative Structure for Science, Technology and Innovation Policies	125
2 Revitalizing the flow of funds to create knowledge and value	127
<b>Chapter 2 Science, Technology and Innovation Policy Toward Realization of Society 5.0</b>	<b>131</b>
Section 1 Transformation to a sustainable and resilient society that ensures the safety and security of the people	131
1 Creating New Value through the Fusion of Cyberspace and Physical Space	131
2 Promoting Social Change and Disruptive Innovation to Overcome Global Issues	137
3 Building a Resilient, Safe and Secure Society	164
4 Formation of an innovation ecosystem that will serve as the foundation for creating new industries for value co-creation	186
5 Urban and regional development that will serve as infrastructure to pass on to the next generation (development of smart cities)	194
6 Promoting R&D and social implementation to resolve various social issues and utilizing Convergence Knowledge	196
Section 2 Expanding the frontier of knowledge and strengthening research capabilities as a source of value creation	220
1 Reconstruction of the environment that generates diverse and outstanding research	221
2 Construction of a new research system (promotion of open science and data-driven research, etc.)	238
3 Promoting university reform and enhancing functions for strategic management	248
Section 3 Education and Human Resources Fostering to Realize the Well-being of Individuals and the Challenges They Face	253
Supporting Materials	265


 Figures and Tables


 Part 1

Table 1-1-1:	Japanese Nobel laureates (in natural sciences) .....	5
Figure 1-1-2:	Minister Suematsu congratulates Nobel Prize winner in physics, Syukuro Manabe, via videoconference (October 2021) .....	6
Figure 1-1-3:	Changes in the world ranking of major countries for the number of papers and number of adjusted top 10% papers .....	7
Table 1-1-4:	Number of papers and number of adjusted top 10% papers by country: top 10 countries (Fractional counting) .....	8
Figure 1-1-5:	Changes in the number of papers and number of adjusted top 10% papers of major countries (moving average over 3 years, fractional counting) .....	9
Figure 1-1-6:	Changes in Japan's number of papers by type of organization (moving average over 3 years, fractional counting) .....	10
Figure 1-1-7:	Number of papers and number of adjusted top 10% papers by sector and university group in Japan .....	11
Figure 1-1-8:	Estimated changes in the number of papers obtained by the whole counting for all universities (fields of science, engineering and agriculture) .....	12
Figure 1-1-9:	Distribution of the number of papers from German, English and Japanese universities (As of the years 2013 - 2017) .....	13
Figure 1-1-10:	Changes in the ratio of time spent on work activities by university faculty members in all fields .....	15
Figure 1-1-11:	Changes in the ratio of time spent on work activities by university faculty members by academic field .....	15
Figure 1-1-12:	Changes in the annual total working hours of university faculty members .....	16
Figure 1-1-13:	Changes in the annual total working hours of university faculty members (excluding the medical sciences field) .....	16
Figure 1-1-14:	Changes in the number of working hours of university faculty members (by age group) .....	17
Figure 1-1-15:	Percentage of responses related to the four factors considered as constraints by university faculty members in improving research performance .....	18
Figure 1-1-16:	Percentage of responses related to specific constraints in terms of the factors (research time and research funds) felt as constraints by university faculty members in improving research performance .....	19
Figure 1-1-17:	Changes in the Number of Researchers in Major Countries, etc. ....	21
Figure 1-1-18:	Changes in the number of researchers per population of 10,000 in major countries, etc. ....	22
Figure 1-1-19:	Changes in the number of researchers by the field at national universities, etc. ...	23
Figure 1-1-20:	Changes in the percentage of full-time university faculty members by age group .....	24

---

Figure 1-1-21:	Percentage of Female Researchers in Various Foreign Countries	25
Figure 1-1-22:	Changes in the number of students enrolled in the doctor's course	26
Figure 1-1-23:	Changes in the number and percentage of students advancing from master's course to doctor's course	26
Figure 1-1-24:	International comparison of doctoral degree recipients per million population	27
Figure 1-1-25:	Number of research assistants per researcher in major countries, etc.	28
Figure 1-1-26:	Changes in the ratio of total R&D expenditures to GDP in major countries	29
Figure 1-1-27:	Ratio of government-funded research expenditure to GDP in major countries, etc.	30
Figure 1-1-28:	Changes in the ratio of government budget appropriations for science and technology to GDP in major countries	31
Figure 1-1-29:	Changes in the Gross Domestic Product (GDP) of major countries (OECD purchasing power parity equivalent)	32
Figure 1-1-30:	Index of R&D expenditures in university sector (nominal amount (OECD purchasing power parity equivalent)) on a 2000 base year	33
Figure 1-1-31:	Index of R&D expenditures in public institution sector (nominal amount (OECD purchasing power parity equivalent)) on a 2000 base year	33
Figure 1-1-32:	Index of R&D expenditures in business enterprise sector (nominal amount (OECD purchasing power parity equivalent)) on a 2000 base year	34
Figure 1-1-33:	Changes in research expenditure per full-time researcher	34
Figure 1-1-34:	Changes in domestic papers and internationally co-authored papers in the number of papers and number of adjusted top 10% papers (whole counting)	35
Figure 1-1-35:	Relationship between domestic and internationally co-authored papers	36
Figure 1-1-36:	Ratio of Q index for domestic papers and internationally co-authored papers (two countries and multiple countries)	37
Figure 1-1-37:	Changes in the number of researchers dispatched abroad (short-term and mid-to-long-term)	38
Figure 1-1-38:	Ratio of researchers dispatched abroad (mid-to-long-term) to researchers enrolled at research institutions	39
Figure 1-1-39:	Changes in doctoral degree recipients in the U.S. by country and region	40
Table 1-1-40:	Number of patent families in major countries/regions (top 10 countries/regions)	41
Table 1-1-41:	Number of papers cited in patent families: Top 25 countries/regions	42
Figure 1-1-42:	Changes in industrial trade value in major countries	43
Figure 1-1-43:	Changes in the amount received (breakdown) and the number of joint research projects between Japanese universities and the private enterprises	44
Figure 1-1-44:	Number of unicorn enterprises by industry and country (total of 2010 to 2020)	45
Figure 1-2-1:	The 6th Science, Technology, and Innovation Basic Plan	47
Figure 1-2-2:	The 6th Science, Technology, and Innovation Basic Plan (Overview)	48
Figure 1-2-3:	Overview of the STI Policy	49

Figure 1-2-4:	Changes in government subsidies for national university corporations	52
Figure 1-2-5:	Changes in competitive funding	52
Figure 1-2-6:	Government-funded R&D expenditures by university group	53
Figure 1-2-7:	Overview of Grants-in-Aid for Scientific Research (KAKENHI)	54
Table 1-2-8:	List of major applications and improvements for Grants-in-Aid for Scientific Research	54
Figure 1-2-9:	Strategic Basic Research Programs	55
Figure 1-2-10:	List of WPI Centers	56
Figure 1-3-1:	Comparison with universities in other countries in terms of growth index	59
Figure 1-3-2:	Comparison with universities in other countries in terms of fund value	59
Figure 1-3-3:	Future image of Universities for International Research Excellence (conceptual diagram)	59
Figure 1-3-4:	Toward formation of a diverse group of research universities	60
Figure 1-3-5:	Overview and targets of support provided to doctoral students in Japan	63
Figure 1-3-6:	Diversification of “time” and “space” for learning, with emphasis on children’s characteristics (target concept)	64
Figure 1-3-7:	Percentage of women among students enrolled in universities and other higher education institutions of OECD member countries	65
Figure 1-3-8:	Mechanism of the URA system in Japan	73
Figure 1-3-9:	Development of collaboration with external research institutions (conceptual image)	76
Figure 1-3-10:	Examples of approaches used to set usage fees	77
Figure 1-3-11:	“Nanotechnology Platform Japan” Promotion System	78
Figure 1-3-12:	“Materials DX Platform” concept	79
Figure 1-3-13:	Changes in the status of Japanese students studying abroad	83
Figure 1-3-14:	Examples of prominent Japanese Government Scholarship students (1,595 in total) who are active (survey conducted in November 2019)	83
Figure 1-3-15:	Changes in the number of international students	84
Figure 1-4-1:	Moonshot Goals	86
Figure 1-4-2:	Society aimed at by Moonshot Goal 8	87
Figure 1-4-3:	Society aimed at by Moonshot Goal 9	87
Figure 1-4-4:	Dynamic map	88
Figure 1-4-5:	15 potential tasks for the next phase of the SIP (target areas)	89
Figure 1-4-6:	14 key sectors listed in the Green Growth Strategy	90
Figure 1-4-7:	Initiatives of the centers	93
Figure 1-4-8:	[Supplemental version] Overall summary	94
Figure 1-4-9:	Guideline search tool and FAQ	95
Figure 1-4-10:	Development of new instruments and diagnostic methods for novel coronavirus infection	99
Figure 1-4-11:	Progress in the development of novel Corona vaccine (domestic development) <Major Items> (as of May 10, 2022)	100

Figure 1-4-12:	Main medicines currently in development for novel coronavirus (as of April 1, 2022) .....	100
Figure 1-4-13:	Light absorption spectrum of hemoglobin (Hb) .....	102
Figure 1-4-14:	Digital detection technology for viral RNA .....	103
Figure 1-4-15:	Mechanism of mRNA vaccine .....	104
<b>Part 2</b>		
Table 2-1-1:	List of CSTI members .....	117
Figure 2-1-2:	The Moonshot Research and Development Program .....	119
Table 2-1-3:	Projects of Moonshot Goal 1 to 7 .....	120
Table 2-1-4:	Projects of Moonshot Goal 8 .....	122
Table 2-1-5:	Projects of Moonshot Goal 9 .....	123
Table 2-1-6:	Major decisions and reports from CST (FY2021) .....	126
Table 2-1-7:	Organizational structure of the Science Council of Japan (SCJ) .....	127
Table 2-1-8:	Changes in science and technology budgets .....	128
Table 2-1-9:	Science and technology budgets of each ministry/office/agency .....	129
Figure 2-1-10:	R&D taxation system .....	130
Figure 2-2-1:	The Nankai Trough Seafloor Observation Network for Earthquakes and Tsunamis (N-net) .....	166
Figure 2-2-2:	Innovative Science & Technology Initiative for Security .....	184
Figure 2-2-3:	Transition in achievements of joint research at universities .....	188
Figure 2-2-4:	Percentage of female researchers by country .....	226
Figure 2-2-5:	Changes in the number of researchers dispatched abroad (short-term and mid-to-long-term) .....	231
Figure 2-2-6:	Changes in the number of foreign researchers overseas (short-term and mid-to-long-term) .....	232
Figure 2-2-7:	Measurement accuracy inspection by master meter method .....	245
Figure 2-2-8:	Distribution map of Ito Ignimbrite and associated deposits, Aira Caldera (abs.) .....	246
Figure 2-2-9:	Image of “Innovation Commons (co-creation campus)” at National Universities .....	251
Figure 2-2-10:	Image of “Innovation Commons (co-creation campus)” at National Universities .....	252
Figure 2-2-11:	Participants in the International Student Contests in Science and Technology (FY2021) .....	254
Figure 2-2-12:	The 9th Japan Junior High School Science Championships .....	256
Figure 2-2-13:	The 11th Japan High School Science Championships .....	256
Figure 2-2-14:	Breakdown of successful candidates of the Second-Step Professional Engineer Examination by Technical Discipline (FY2021) .....	259



## Columns

1-1	“FOREST Researchers” Taking on Challenges	62
1-2	Why is the number of women majoring in physics and mathematics less?	66
1-3	Establishment of the First Engineering Department at a Women's University	69
1-4	“Brilliant Female Researchers Award (The Jun Ashida Award)”	70
1-5	Through AI analysis, the strength (product of maximum energy) of a neodymium magnet on a laboratory scale improved by about 1.5 times compared to before and after conventional analysis in about 40 experiments.	75
1-6	Toward a Society where Everyone can Take Challenges - The Potential of Science, Technology and Innovation -Daredemo Piano (Auto-Accompanied) -	96
1-7	2022 Edition of the annual S&T poster for everyone “One S&T Poster for Every Household - Glass: The Most Universal Modern Material”	112
2-1	Direct Air Capture, the Last Trump Card Against Global Warming	139
2-2	Discovery of a New Species of Bacteria in the Stomachs of Dairy Cows, which is Expected to Limit Methane Generation - Potential Contributor to the Reduction of Methane Emissions from Cow Burps -	143
2-3	Rich Data Is the First Step in Creating High Quality Research Results! ~Observations and Results at the Polar Regions~	147
2-4	Understanding the Impact of the COVID-19 Pandemic on the Global Environment	149
2-5	A Next-generation Geological Map That Can Express the Subsurface Geological Structure in Three Dimensions (Urban Geological Map)	169
2-6	Developing a Food Supply System in Space	180
2-7	Understanding the Large Amount of Drift Pumice from the Fukutoku-Okanoba Eruption	182
2-8	R&D Related to AI in the Field of Defense	185
2-9	Realization of modularized quantum light source toward fault-tolerant large-scale universal optical quantum computers ~ Developed a fiber-integrated quantum light source ~	199
2-10	Prediction of 3D Position of Pests by Modelling Their Flight pattern	205
2-11	Visualizing the Activities of Laboratories and Research Groups: Labo-Panel Survey	224
2-12	The Leiden Manifesto for Research Metrics	230
2-13	Science, Technology and Innovation White Paper Search	240
2-14	Bringing You the Latest from the World of Science, Technology and Innovation: Information Website "Science Portal"	263