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Technology Foresight surveys in China

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1 Introduction

In February 2006, the Chinese government announced its National Guidelines for Medium- and Long-term Plans for Science and Technology Development, which set forth the direction of science and technology promotion for the next 15 years[1]. Under the guidelines, research and development expenditures across the entire spectrum of society are to be raised to at least 2.5 percent of GDP by 2020, the contribution rate of science and technology to GDP growth is to reach at least 60 percent, dependence on foreign technology is to be reduced to 30 percent or lower, and China is to move into fifth place in the world in terms of patents obtained and science and technology papers cited. Additional goals to be achieved by 2020 include the following: (1) Enhancing China's innovation capacity in order to strengthen the country's ability to use science and technology to promote economic and social development and safeguard national security, supporting the building of "a little well-off (xiaokang) society. (2) Stronger overall capabilities in basic science and frontier technology research, producing results of international importance, making China one of the innovation-oriented nations, and laying the foundation for China to become a world science and technology power by mid-century. Meanwhile, progress is being made on setting the 11th Five-Year Plan. At the National People's Congress held in March, adjustment of industrial structure and development that is balanced among different regions were discussed and adopted.

In line with this movement to firm up plans, the Ministry of Science and Technology and the Chinese Academy of Sciences[2] since 2002 have carried out technology foresight survey and published a series of reports. The Ministry of Science and Technology occupies a position similar to that of a ministry in Japan, while the Chinese Academy of Sciences is an operational department that reports directly to the State Council. It is China's largest scholarly organization in the natural sciences as well as a comprehensive research center. The Chinese Academy of Sciences incorporates six academic divisions, about 90 research institutions, and 12 branches. It has around 700 members (academy members) and 46,000 employees (according to its 2005 annual report). Technology foresight survey had been carried out in the special administrative regions of Beijing and Shanghai, and also in Wuhan, but this was the first time it had been carried out at national level in connection with planning for the development of science and technology.

Both the Ministry of Science and Technology and the Chinese Academy of Sciences adopted the method of examining concepts of future societies (or needs) and using Delphi analysis with questionnaires on technological development. Delphi analysis is a survey method involving repeated identical surveys of many experts to draw out a consensus of respondents' opinions. It has been used in Japan about every five years since 1971 (The National Institute of Science and Technology Policy has administered the program since the 5th survey.)[3]. The Delphi questionnaires are modeled on the Japanese method and have many similarities, including the method of carrying out the survey twice in order to obtain a consensus of opinions, question categories, and evaluation methods.

This report provides an overview of both

Chinese foresight surveys and highlights notable statements and data in order to provide a reference for those involved in science and technology policy planning and implementation.

2 Technology Foresight survey by the Ministry of Science and Technology

The Ministry of Science and Technology has been carrying out technology foresight survey since 2002. The research itself is conducted by the National Research Center for Science and Technology for Development, which is affiliated with the Ministry of Science and Technology. The purpose of the survey is to "clarify major technologies for China's socioeconomic development for adoption in the National Guidelines for Medium- and Long-term Plans for Science and Technology Development and the 11th Five-Year Plan," making clear its relationship to both plans.

The survey has a three-stage structure. The first stage comprises analysis of socioeconomic needs and science and technology trends, together with design of the Delphi survey sheets. The second stage is analysis of the Delphi questionnaire and its results. The third stage comprises selection of nationally important technologies and the creation of reports.

2-1 Survey target fields and questions

First, a survey covering the three high-tech fields of information and communications, biotechnology and life science, and new materials was carried out during 2002-2004. Next, a survey covering energy, resources and environment, and advanced manufacturing technology was conducted during 2004-2005. A survey of three more fields, agriculture, public safety, and population and health, began in autumn 2005. These cover most of the 11 major areas (energy, water and mineral resources, environment, agriculture, manufacturing industries, transportation, information services, population and health, urbanization, public safety, and national defense) found in the National Guidelines for Medium- and Long-term Plans for Science and Technology Development. In particular, the three areas now being surveyed fall within those major areas. To date, reports have been published for the six fields through to "advanced manufacturing technology." Separate internal documents have been created regarding "nationally important technologies."

Technologies targeted by the survey are organized into "fields, sub-domains, and technology topics." As shown in Table 1, there are 6 fields, with 42 sub-domains and 483 technology topics.

The questions regarding technology themes covered 17 items, including predicted time of

Table 1 : The 42 sub-domains set forth in the foresight survey of Ministry of Science and Technology

Field	Sub-domains
Information and communications (6 sub-domains, 75 topics)	Computers, computer network and information security, communications, software, integrated circuits, video and audio
Biotechnology and life science (4 sub-domains, 83 topics)	Agricultural biotechnology, life science, industry and environment, medicine
New materials (4 sub-domains, 64 topics)	High-performance structural materials, new functional materials, electronic information materials, nanomaterials
Energy (9 sub-domains, 83 topics)	Coal, oil and gas, electric power, nuclear energy, renewable energy, hydrogen energy and other new energies, building energy coservation, Industry energy conservation, transportation conservation
Resources and environment (6 sub-domains, 100 topics)	Ecology and environment, solid mineral resources, oil and gas resources, land resources, ocean resources, water resources
Advanced manufacturing technology (13 sub-domains, 78 topics)	Advanced manufacturing models, digital engineering for equipment, manufacturing flow automation, digital design, environmentally friendly manufacturing technology, micro-nano manufacturing technology, energy sources equipment, transportation equipment, process manufacturing, agricultural equipment, environmental protection equipment, household electrical appliances, marine engineering

Source: Reference [4]

realization, importance, effects, China's technical level, and government policies. A number of items concern application in society and industrialization. Among these are the potential for obtaining intellectual property rights, industrialization outlook and costs, and predicted time of realization (time for industrialization). Furthermore, 3 of the 5 items asking about results are industry-related (promotion of high-tech industrial development, promotion of the development of existing industry, and increased international competitiveness). In addition, it is notable that there are questions concerning national security, but the results are not included in the reports.

The forecast period varies according to field: 10 years for information and communications, biotechnology and life science, and new materials; 15 years for energy, resources and environment, and advanced manufacturing technology.

Respondents to the questionnaire (experts who responded to the second round) numbered 130-180 for each field, totaling 929.

2-2 Examination of science and technology needs

Examination of science and technology needs for China's economic and social development was undertaken from the 10 perspectives listed below. At the same time, analysis of China's internal and external environments for scientific and technical development was carried out. This contributed to the selection of technology themes.

(1) Optimization of industrial structure
(2) Development of agriculture
(3) Development of high-tech industry
(4) Pressure of international trade
(5) Urbanization
(6) Population and health
(7) Overall resource use and sustainable development of society
(8) Optimization of energy structure
(9) Environmental improvement
(10) National security

2-3 Notable survey results

(1) Self-assessment of China's technical levels

Respondents assessed China's technical levels as being five years behind those of the leading countries for about 90 percent of technology topics. On the other hand, levels for about 10 percent of topics in the information and communications, biotechnology and life science fields are rated as being on a par with those of

Table 2 : Technologies in which China's level was assessed as being on a par with those of the leading countries

Field	Number of topics	Technology topics
Information and communications	6	• Chinese-language information processing technology • Regional networks • Broadband connection technology • Third-generation mobile phone systems (TD - SCDMA = Time Division - Synchronous Code Division Multiple Access) • DVD technology based on IP • Industrialization of multi-wavelength, multi-stage, high-density video disks
Biotechnology and life science	7	• Core technology for genome base sequencing • Technology for genetic engineering of plants • Technology for cloning animal somatic cells • Technology for adjusting the natural ingredients of medicines • Reagents for quick verification and diagnosis of serious and infectious diseases • Molecular markers and new species for major crops through biotechnology • New varieties of high-quality, mass-produced genetically engineered crops
New materials	6	• Technology for large-area, high-quality, artificial crystal materials and all-solid lasers • Shape-memory materials • Manufacture of nanocomposite materials • Manufacturing design and assembly on the nanometer level • Atom and molecular assembly through direct manipulation • Technology for nanomaterial performance characteristics and devices
Energy	2	• Development of watersheds for hydroelectric power • Ultralarge-scale electric power safety systems

Source: Reference [4]

the leaders. In the new materials field, 9 percent of topics were at the same level as the leading countries, while 14 percent were 6-10 years behind. The field of advanced manufacturing technology was assessed as being furthest behind, with 70 percent lagging 5 years behind and 30 percent 6-10 years behind. Themes seen as being at the same level as those of the leading countries are shown in Table 2.

For example, basic research in nanotechnology and nanomaterials is assessed as being at the same level as that of the leading countries. While China is at international levels in the compounding of nanomaterials such as carbon nanotubes, and matches the leading countries in R&D on nanocomposite materials, metal, ceramic, glass, and polymer nanomaterials, nano-oxides, single nanoparticles for semiconductors and metals, nanofilm layers, nano-functional materials, etc., it lags well behind in terms of their application to integrated circuits, etc.

As for genetic technology, technical levels in genome-sequencing analysis, research on human functional genomics, genetic engineering technology, molecular markers, cloning of animal somatic cells, etc., are seen as being at the same level as those of the leading countries.

In the information and communications field, third-generation mobile communications, optical networks, integrated switch routers, next-generation networks, and so on are said to be close to international levels. However, computers, software, and network and information security are seen as being five years behind the leaders, while research and development capability on integrated circuits is even further behind.

Regarding desirable research and development methods, autonomous research and development accounts for 60 percent of responses in all technology topics, but joint research accounts for 60 percent in the information and communications field and 50 percent in the biotechnology and life science field. In new materials, autonomous research and development accounts for 70 percent of the responses.

(2) Degree of importance

Looking at the 100 topics seen as most important, the information and communications and biotechnology and life science fields account for about half, with 26 and 22 topics, respectively.

In concrete terms, these include information security technology; network security technology; supercomputer system design; research on next-generation network architecture; low-cost, high-performance, leading-edge steel materials; reagents for the quick verification and diagnosis of serious and infectious diseases; Chinese-language information processing technology; systems for managing network computing environments; new-type and general-purpose IC production; and research and production of 64-bit high-performance CPU chips.

(3) Analysis of economic effects

The report includes analysis by question item as well as overall analysis. For economic effects in particular, an economic costs index is derived from three questions regarding industrialization outlook, international competitiveness, and industrialization costs. Technology topics are classified based on their characteristics in terms of economic effects × high-tech industry promotion effects / development and structural improvement of existing industry promotion effects / environmental conservation and resource development effects.

Technology topics with high promotion effects for high-tech industry may be either high or low in terms of economic effects, but technology topics with high promotion effects for existing industry have high overall economic effects. There is a tendency to promote high-tech fields in the future, but because China will depend on existing industries for the coming 5-10 years, their analysis holds that innovation in those fields must be accelerated.

(4) Breakthrough technologies with a high likelihood of realization in China

The information and communications, biotechnology and life science, and new materials fields are cited as offering breakthrough technologies with a high likelihood of realization

Table 3 : Breakthrough technologies with a high likelihood of realization in China in the coming 10 years

Information and communications	Next-generation mobile communications technology, next-generation network systems, nanochip technology, Chinese-language information processing technology
Biotechnology and life science	Human functional genomics, biomedical technology, bioinformatics, proteomics, technology for cultivating new crop species
New materials	Nanomaterials and nanotechnology

Source: Reference [4]

Table 4 : Core technologies with a high likelihood of dramatic industrial development in China

Information and communications	SoC (system on chip) technology, next-generation mobile communications technology, organic electroluminescence (EL) technology, digital communications, compression, Codec technology
Biotechnology and life science	Biotechnology for medicines and vaccines, technology for biocatalysts and genetic engineering, genetically engineered crops with high quality, productivity and resistance
New materials	Low-cost, high-performance, leading-edge steel materials; technology for manufacturing materials and measuring

Source: Reference [4]

in China in the coming 10 years (Table 3) and core technologies with a high likelihood of dramatic industrial development in China (Table 4). In the Japanese survey, the outlook for technical development in Japan alone is not considered.

3 Technology Foresight survey by the Chinese Academy of Sciences

The Chinese Academy of Sciences carried out technology foresight survey for four fields (information, communications, and electronics; energy; materials science; and biology and drugs) from 2003 through 2005. The survey was carried out by the Institute of Policy and Management of the Chinese Academy of Sciences. Surveys of another four fields (manufacturing technology, resources and environment, chemistry and chemical engineering, space technology) are now underway, with publication of results expected around the summer of 2006.

The report entitled “Technology Foresight for Future 20 Years in China”[5] distinguishes between “technology forecasting” and “technology foresight,” suggesting that recently “foresight” has been developed beyond the “forecasting” of the first half of the 20th century. The report argues that “foresight” obtains better results than “forecasting” by identifying future needs and preparing the capabilities required to address those needs. The following four reasons are given for the emphasis on “foresight.”

(1) It is a tool for determining areas that should take priority.

(2) It is a means of strengthening national innovation.

(3) It lowers the cost of creating proper investment strategies for small- and medium-sized businesses by enabling them to ascertain the direction of trends in future technology development.

(4) It enables early warning of negative social and environmental impacts of technologies.

Items of particular interest within the report are the “Six Visions for Chinese Society in 2020,” which were determined in 2003 and provided the basis for selection of technology themes, and the results of analysis of world technology levels, especially in relation to those themes in which Japan is seen as leading the world. Below, we discuss the report's content, with particular focus on those aspects.

3-1 Target fields and questions

In the Chinese Academy of Sciences foresight survey, the four fields (information, communications, and electronics; energy; materials science; and biology and drugs) incorporate 32 sub-areas and 409 technology topics. Aspects such as each theme’s importance, time of realization, potential for realization, the relative levels of leading countries and China,

Table 5 : The 32 sub-areas set forth in the Foresight survey of Chinese Academy of Sciences

Field	sub-areas
Information, communications and electronics (12 sub-areas, 150 technological topics)	(1) Computer technology, (2) software technology, (3) communications technology, (4) network technology, (5) broadcast and television technology, (6) man-machine and artificial intelligence technology, (7) information security technology, (8) bioinformatics, (9) microelectronic, photoelectronic, and micromachine technology, (10) information gathering and sensor technology, (11) information storage and display technology, (12) application of information technology
Energy (6 sub-areas, 72 technological topics)	(1) Coal, oil, natural gas, (2) electric power, (3) nuclear power, (4) hydrogen energy, (5) reusable energy, (6) thermal and mechanical energy
Materials science (6 sub-areas, 86 technological topics)	(1) High-polymer materials, (2) metal materials, (3) inorganic and ceramic materials, (4) functional materials, (5) photoelectronic materials, (6) nanomaterials
Biology and drugs (8 sub-areas, 101 technological topics)	(1) Bio-platform technology, (2) biomeasurement and bioengineering technology, (3) technology for promoting organism growth and improvement of species, (4) agricultural and environmental science, (5) disease prevention and cure, (6) new drug discovery and development, (7) stem cells and regenerative medicine, (8) cognitive and behavioral science

limits on development, etc. are analyzed. Table 5 shows the names of the 32 sub-areas. The 409 technology themes are listed in an appendix in order of their time of realization, from earliest to latest. The period examined is the 15 years ending in 2020.

The names of the 268 sub-area experts and the 975 respondent experts are also listed in an appendix at the end of "Technology Foresight for Future 20 Years in China." There is very little overlap between the two groups.

Not all the collected data are included in the report. Instead, only the top 10 items for each field and perspective are shown in most cases, so it is not possible to study the detailed results of the entire survey.

3-2 A picture of China's science and technology in 2020

Of note in the report are the following six visions set forth in Section 1, "Visions for an overall xiaokang society in China in 2020," in Chapter 3, "What is required of science and technology to build a little well-off (xiaokang) society." A little well-off society is a society in which "the people of China, who already number 1.3 billion, can live with a certain degree of happiness." In this technology foresight survey, Chinese society in 2020 is viewed as follows:

(1) Globalized society

World trends include an increase in the number of powerfully competitive multinational corporations, the globalization of production and finance using information technology, and other movements that ignore national borders. The flow of science and technology human resources and international cooperation are also progressing dramatically.

In accordance with this world trend, by 2020 China will have worked to expand its ability to absorb foreign investment and to invest in foreign countries, dramatically enhancing its "resource allocation ability" in a globalized society in terms of intellectual production, technology transfer, application capability, resource development and utilization capabilities, etc.

(2) Industrialized society

China's industrial structure currently has a high ratio of primary industries such as agriculture, unlike the advanced industrial nations. However, China's industrialization is already remarkable. The shift of workers from primary to secondary and tertiary industry will be promoted, lowering the share of primary industry to 6.75 percent by 2020, and raising the share of secondary and tertiary industry to more than 93 percent.

(3) Information society

Led by the major coastal cities in the east, China's use of information technology is rapidly expanding. China is now implementing measures that will enable it to become an information society, such as application of information technology, accumulation of information resources, preparation of information networks, the fostering of informatization human resources, and the establishment of laws and standards that accompany informatization. By 2020, China aims to have 40 computers, 7 network servers, 50 fixed telephone lines, 50 mobile telephones, 50 digital televisions, and 40 Internet users per 100 people.

(4) Urbanized society

In contrast to the progress of industrialization, the rate of urbanization is remarkably slow. By 2020, China will have transferred an excess rural population of 200 million people into the urban workforce, raising the urban proportion to 64 percent of total population.

(5) Recycling-oriented society

Against the backdrop of a natural environment that is deteriorating due to global warming, air pollution, etc. resulting from such impacts as industrialization, China is interested in developing a recycling economy, reuse of waste, etc. Aiming for realization of a little well-off society that efficiently employs science and technology to both utilize and conserve resources is the first step in building a recycling-oriented society.

By 2020, Chin's coastal area will be a vast model zone for a recycling economy, with energy consumption reduced by half from 2001 rates, and carbon-dioxide emissions per unit GDP reduced by 30-40 percent.

(6) Consumer society

As used in the report, a "consumer society" is one that aims for a more affluent, healthy, convenient, and safe life. At this point, China is pursuing realization of a consumer society by improving the quality and variety of its food and clothing, developing technology for healthcare and disease prevention, and improving public transportation. China projects a per capita GDP of at least $3,000 US (triple the 2002 figure) by 2020. The nation's wealthiest class now enjoys incomes up six times those of the poorest segment of the population (each accounting for 10 percent of all households), but the percentages of household budgets spent on food, clothing, housing, healthcare, light and heat, transportation, etc. do not differ to any great extent. For example, spending on healthcare is about 8 percent of household budgets for all income levels. National government investment in technical development for healthcare, pharmaceuticals, hygiene, etc. is expected to lower the percentage spent on healthcare at all levels of society. In addition, conservation of water resources, traffic safety, food safety, etc., are cited as areas requiring science and technology input in a consumer society.

3-3 Noteworthy survey results

(1) Japan's technical levels from the Chinese perspective

The following items are noted for each field: (i) an overview, (ii) the most important technology topics in the field, (iii) predicted time of realization for technology topics, (iv) China's research and development levels in those topics, (v) advanced countries in the technology topics (USA, EU, Japan), (vi) potential for realization of the technology topics, and (vii) elements constraining technical development. The results of comparisons between China's technical levels and those of the other countries are particularly interesting.

Research and development levels are shown on a scale of 0 to 1 point. If all respondents answer, "Leads the world," the score is 1.0; if all respondents answer "Close to world level," the score is 0.5; and if all respondents answer, "Trails the world," the score is 0.0. Looking at the assessment of China's research and development levels, the highest score is 0.31 for the information, communications, and electronics area; 0.56 for energy; 0.60 for materials science; and 0.53 for biotechnology. With the world number one in each area obtaining a score of at least 0.7, this is quite a low self-assessment.

The advanced countries in the technology topics are almost limited to the USA, the EU, and Japan (the only other countries appearing are Russia and South Africa). Japan is seen as number one in 1 technology topics in information, communications, and electronics; 5 in energy; 12 in materials science; and 6 in biology and drugs. Because it is of interest to note in which technologies China sees Japan as leading the world, these are shown in Table 6 (including some where Japan is at the same level as the USA).

The USA is seen as having by far the highest level in the information, communications, and electronics field, with Europe and Japan lagging well behind. It is notable that the only area in which Japan is seen as number one in the field - tied with the USA - is the topics of semiconductor white lighting technology, which was achieved based on technical development of blue LEDs. In the materials science field, Japanese technology in high-polymer materials did not beat the USA for any topics, but in the other five sub-areas, Japan was seen as first in one to four technology topics. In addition, Japan is seen as surpassing Europe in most topics in the materials science field. In the biology and drugs field, the existence of three technology topics related to Chinese herbal medicine is striking. Japan's technical level is seen as much higher than that of China, the

Table 6 : Technologies where Japan is seen as being in 1st place

Field	sub-area	Technology topics
Information, communications and electronics (1 topics)	Microelectronic, photoelectronic and micromachine technology	• All-solid semiconductor white lighting technology
Energy (5 topics)	Electric power	• New types of permanent-magnetic motors • Various energy-saving technologies
	Hydrogen energy	• Direct manufacture of hydrogen through highly efficient photolysis
	Thermal and mechanical energy	• Hybrid cars • Efficient, comprehensive handling of urban waste
Materials science (12 topics)	Metal materials	• Technology for environmentally friendly steelmaking without blast furnaces • Rolling technology that adds heat without oxidation • Development of high-quality, high-speed continuous-casting technology
	Inorganic and ceramic materials	• Ultralarge-scale integrated circuits using thin films with high or low electric constants • Application of lead-free piezoceramic materials to information technology • Technology for platform integration through low temperature co-fired ceramics (LTCC) • Thermoelectric conversion materials with a conversion efficiency of at least 10%
	Functional materials	• Flat information ceramic functional materials and devices • Functional materials from rare-earth elements
	Photoelectronic materials	• Full-color large-screen projection technology with all-solid lasers • Polishing and extension chips for 450-mm diameter silicon
	Nanomaterials	• Nanoenvironment purification materials
Biology and drugs (6 topics)	Agricultural and environmental science	• Countermeasure technology for red tides and other types of water eutrophication • Urban waste disposal using microorganisms • Healthy and efficient cultured production of sea life
	Disease prevention and cure	• Treatment with Chinese herbal medicine
	New drug discovery and development	• Technology for modernizing Chinese herbal medicine • Model identification methods for Chinese herbal medicine

Table 7 : Number of 1st- and 2nd-place topics

Field	No. of Topics	USA		Japan		EU		Russia		South Africa	
		1st place	2nd place	1st place	2nd place	1st place	2nd place	1st place	2nd place	1st place	2nd place
Information, communications and electronics	150	150	0	1	97	0	55	0	0	0	0
Energy	72	50	17	5	16	15	38	2	1	1	0
Materials science	86	73	11	12	68	2	6	0	1	0	0
Biology	101	94	7	6	23	1	74	0	0	0	0
Total	409	367	35	24	204	18	173	2	2	1	0

medicine's homeland.

Table 7 shows the number of topics in each field in which each country is ranked first or second.

(2) Method of assessing the importance of technology themes

The importance of technology is evaluated from three perspectives, which are combined in a comprehensive index for analysis. The three perspectives (three elements) are: (i) promotion of economic growth, (ii) improvement of quality of life, and (iii) protecting national security.

Responses are aggregated by combining and weighting degree of importance (four levels: very important, important, relatively important, not important) and respondents' degree of expertise (very well informed, well informed, relatively informed, not informed). For the "comprehensive judgment of the three elements," in other words, an overall degree of importance index, the root-sum-square (RSS) value of the "three elements" is used.

The report shows only the order of importance; nowhere does it describe the calculations used to obtain the results.

(3) Elements constraining development

There were six categories of constraints on the development of technology topics: (i) feasibility, (ii) potential for commercialization, (iii) regulation, policy, and standards, (iv) human resources, (v) investment of research and development funds, and (vi) basic infrastructure, with multiple responses possible. The report shows the results for only a few technology themes. The most common leading constraint is investment of research and development funds, with human resources or basic infrastructure often appearing in second place.

3-4 Development trend scenarios for important technology themes

The report of the Chinese Academy of Sciences was published in two parts. The second part is the above-described "Technology Foresight for Future 20 Years in China." In the first part, "Technology Foresight 2005,"[6] published in 2005, experts comment on the 44 technology themes regarded as most important at the time. They generally devote several pages to providing an overview of each technology and describing its significance, technical trends, issues, and China's strategies. Table 8 shows the result of comparing the 44 themes and authors with the results of the Delphi analysis. Looking at degree of importance according to the questionnaire, the energy field in particular has few high-ranked themes. The data for the level index are therefore also unclear.

Most of the experts who wrote the commentaries are specialists in the Delphi survey sub-areas or respondents to the questionnaire. Those marked with a ○ are experts in a sub-area, while those marked with a (are experts who responded to the survey. Some are included in both categories, while others are included in neither.

4 Conclusion

We have described technology foresight survey in China. Based on published reports, we have examined particularly noteworthy elements such as the six visions for a little well-off society that China is pursuing, technologies in which China is on a par with the leading countries, and Japan's technical level as seen from a Chinese perspective. From this, one can discern the direction in which China is moving and its self-assessment of its current status.

This recent technology foresight survey is the first research activity that China has carried out as background material for policy deliberation. Meanwhile, the "8th Science and Technology Foresight Survey"[3] conducted by the National Institute of Science and Technology Policy in Japan was the first survey to be carried out in close cooperation with Japanese policymakers. The necessity and importance of foresight surveys in policy deliberation will increase continuously. The major goal for foresight researchers will be to provide the information needed by policymakers in the most reliable and rational form possible.

China's technology foresight survey and Japan's foresight survey have many points in common, including questionnaire categories and technology classifications. They also share attempts to design research to supplement

Table 8 : Comparison of themes and authors from "Technology Foresight 2005" with questionnaire results from "Technology Foresight for Future 20 Years in China"

Field	sub-area	44 themes used in scenarios, authors and their affiliations			Time of realization	Index of Chinese level	Priority rank
		Theme	Author	Affiliation			
Information, communications and electronics	Computer technology	Tera FLOPS scale microprocessors	○ Zhi-min Tang	Institute of Computing Technology, Chinese Academy of Sciences	2017	0.05	41
		Grid computing	○ Yan-bo Han	Institute of Computing Technology, Chinese Academy of Sciences	2015	0.22	31
	Communications technology	Multifunction personal information terminal	○ Shao-qian Li	University of Electronic Science and Technology of China	2012	0.22	32
		Novel mobile communications providing moving pictures services	△ Jin-kang Zhu	University of Science and Technology of China	2012	0.25	24
		Fourth-generation mobile communication system	○ Shi-xin Cheng	Shanghai for Wireless Communications Research Center	2015	0.28	23
	Network technology	IPV6 networks	○ Zhong-cheng Li	Institute of Computing Technology, Chinese Academy of Sciences	2013	0.31	43
		Wireless sensor network	△ Song-lin Feng	Shanghai Institute of Microsystem and Information Technology, Chinese Academy of Sciences	2015	0.13	30
		Broadband access technologies	△ Xing-gang Wang Hua-shen Zeng	Institute of Computing Technology, Chinese Academy of Sciences Computer and Communication College, Southwest Jiaotong University	2010	0.27	50
	Man-machine and artificial intelligence technology	Speech technology in knowledge acquisition and information interaction	Yong-hong Yan	Institute of Acoustics, Chinese Academy of Sciences	2016		
	Information security technology	Large-scale anti-attack network security systems	Zheng-yue Wei Zhong-hui Wen	No.58 Research Institute of General Staff, PLA Beijing Science and Technology Information Association	2018	0.14	26
	Microelectronic, photoelectronic, and micromachine technology	Processing technology for 10-nm 1000G integrated density	○ Tian-chun Ye	Institute of Microelectronics, Chinese Academy of Sciences	2020	0.07	9
		MicroOptoElectroMechanical Systems (MOEMS)	○ Yue-lin Wang Tie Li	Shanghai Institute of Microsystem and Information Technology, Chinese Academy of Sciences	2016	0.15	59
Energy	Coal, oil, natural gas	Coal gasification and poly-generation	○ Zhen-yu Liu	Institute of Coal Chemistry, Chinese Academy of Sciences	2017	0.12	99
		Floating production technology in offshore oil fields	Xiang-an Yue Xiao-dong Wu	China University of Petroleum Beijing	2017		
		Development of marine gas hydrate exploitation technology	○ Qing-huan Jin △ Jia-qiang Zhang	Guangzhou Marine Geological Survey, Ministry of Land Resource Development and Research Center, China Geological Survey	2022	0.12	15
	Electric power	Ultralarge-scale electric power grids	○ Shu-yong Chen	China Electric Power Research Institute	2013	0.4	4
		Distributed power systems	Zhi-ping Qi ○ Li-ye Xiao	Institute of Electrical Engineering, Chinese Academy of Sciences	2016		
	Nuclear power	High-level radioactive waste disposal technology	△ Xiang-ke Wang	Institute of Plasma Physics, Chinese Academy of Sciences	2021	0.26	
	Hydrogen energy	Fuel cell vehicles	△ Bao-lian Yi △ Ming Hou	Dalian Institute of Chemical Physics, Chinese Academy of Sciences	2017	0.23	
		Distributed hydrogen fuelled generation system	○ Yun-han Xiao	Institute of Engineering Thermophysics, Chinese Academy of Sciences	2016		
	Reusable energy	Bioenergy technology	○ Jie Chang ○ Chuang-zhi Wu	Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences	2015		
		Economical highly-efficient solar power technology	○ An-ding Li	Institute of Electrical Engineering, Chinese Academy of Sciences	2017	0.24	
	Thermal and mechanical energy	High-performance heavy gas turbines	○△ Xin Yuan	Department of Thermal Engineering, Tsinghua University	2016	0.09	

Field	sub-area	44 themes used in scenarios, authors and their affiliations			Time of realization	Index of Chinese level	Priority rank
		Theme	Author	Affiliation			
Materials	High-polymer materials	High-performance rubber	Bai-lin Lv	Beijing Research and Design Institute of Rubber Industry	2014	0.16	11
	Metal materials	Hydrogen energy materials	△ Ke Yang Man-qi Lv	Institute of Metal Research, Chinese Academy of Sciences	2017	0.19	25
		Light-weight high-steongth metallic materials	○ Li-kai Shi	Beijing General Research Institute for Nonferrous Metals	2014	0.22	3
	Inorganic and ceramic materials	Multifunctional and smart micro sensors	○ Wei Pan Qiang Xu	Department of Materials Science and Engineering, Tsinghua University	2016	0.12	39
	Functional materials	High-temperature superconductor technology	Qing Liu Zheng-he Han	Applied Superconductivity Research Center, Tsinghua University	2025	0.34	53
		Solar cells with a conversion efficiency of 50%	Da-ming Zhuang Gong Zhang	Research institute of Functional Membrane and nano-meter material, Department of Mechanical Engineering, Tsinghua University	2022	0.09	1
		Photocatalytic hydrogen production from water	Qi-yuan Chen Ya-hui Yang	Collage of Chemistry and Chemical Engineering, Central South University	2022	0.13	27
	Photoelectronic materials	Semiconductor white lighting	○ Zhan-guo Wang	Institute of Semi-conductors, Chinese Academy of Sciences	2016	0.28	12
		Ultrahigh-density magnetic data storage technology	Jian-wang Cai ○ Shao-hua Cheng	State Key Laboratory of Magnetism, Institute of Physics, Chinese Academy of Sciences	2016	0.16	29
		Ultra-broadband fiber amplifiers in all-optical networking	Wei Chen	Shanghai Institute of Ceramics, Chinese Academy of Sciences	—	—	—
	Nanomaterials	Controllable fabrication of nano-scale materials	Lei Jiang	Institute of Chemistry, Chinese Academy of Sciences	2015		
Biology	Bio-platform technology	Systems biology	Jia-rui Wu	Shanghai Institutes for Biological Sciences Chinese Academy of Sciences	2015		
		High throughput gene expression technology	Yu-yang Li	Institute of Genetics, School of Life Sciences, Fudan University	2015		
	Biomeasurement and bioengineering technology	Detection of pathogens, harmful and genetically modified ingredients in foodstuffs	△ Da-bing Zhang	College of Life Science and Biotechnology, Shanghai Jiaotong University	2011	0.24	7
	Technology for promoting organism growth and improving varieties	Practical technologies of bio-energy, biomaterials and biomass resource	○△ Ping-kai Ouyang	College of Life Science and Pharmacy, Nanjing University of Technology	2014	0.21	2
	Agricultural and environmental science	Microbial metabolic engineering (cell factory)	△ Zhu-an Cao Yin Li	Department of Chemical Engineering, Tsinghua University School of Biotechnology, Southern Yangtze University			
		Molecular design of plant cultivars and molecular breeding	○△ Ai-min Zhang Dao-wen Wang Xiang-qi Zhang	Institute of Genetics and Developmental Biology, Chinese Academy of Sciences	2017	0.36	28
	Disease prevention and cure Stem cells and regenerative medicine	Conquer multifactorial disorders	Jian-jun Gao	Shanghai Institutes for Biological Science, Chinese Academy of Sciences	2014	0.23	QoL 16
		Biodefence preparedness to ensure national safety and public health	Shun-qing Xu	Research Institute of Environmental Medical, Tongji Medical College, Huazhong University of Science and Technology	2012	0.16	10
		Technologies for the isolation, proliferation and differentiation of stem cells	○△ Xue-tao Pei	Institute of Transfusion medicine, Academy of Military Medicine	2022	0.11	
	Cognitive and behavioral science	Artificial intelligence resembling a brain (BAI)	○△ Yue-jia Luo	Key Lab of Mental Health, Institute of Psychology, Chinese Academy of Sciences	—	—	—

○: Expert in sub-area △: Responden —: Excluded from survey No priority rank: Rank is 100 or lower QoL: Rank from a quality-of-life perspective

Prepared by the STFC based on "Technology Foresight 2005" and "Technology Foresight for Future 20 Years in China" the limitations of Delphi analysis, such as examination of visions of future societies and needs and comments on development trends for important technologies. In addition, issues that must be addressed are the same for both: means of integrating various methods, handling of academic fields, and examination of methods to obtain useful data. Regarding the setting of technology themes, they have also taken steps to obtain contributions from outside experts, involve relevant research institutions and academic societies, and associate questionnaires and other methods. It would be beneficial for foresight researchers from various countries to exchange opinions based on their experiences.

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(Original Japanese version: published in March 2006)