10. Survey Results in “Production and Machinery”

10.1. Trends in areas of attention

10.1.1. Introduction

Future technologies are already here. That is, some potential future technologies already exist in present-day technologies.

This survey covers a time span of 30 years, which is a generation. It is a long time during which the world could undergo significant changes, but not long enough to see all things that are familiar disappear.

The year 2000 may be described as a watershed which marks the end of an extraordinary millennium. Of the major events of the millennium, the rise of industrial culture is particularly remarkable. It may not be an overstatement to say that the last 1,000 years are best characterized by an exponential progress in science and technology, while it is important to give careful thought to the fact that the 21st century holds a double-edged sword of “a paradise or ruin”. So far, we have brought on the following problems by behaving as if we were the master of nature:

1) Depletion of natural resources
2) Environmental changes due to human activities.

Taking this into account, therefore, a new industrial culture must be developed. In this context, we would like to discuss the basis of technological forecasts in the “production and machinery” field.

Since the dawn of history, human beings have been building their societies through the skillful use of tools. The Industrial Revolution introduced “machinery and equipment”, which surpassed humans in terms of power and speed, and gave birth to the “production technology” field.

Subsequently, “machinery and equipment” gradually picked up some of the human skills, and displayed “adroitness”, a human-like quality, in many applications. People's initial fear about “machinery and equipment” gradually gave way to a sense of awe. However, this soon developed into a kind of “collusion”, and humans began to treating nature like a slave, using “machinery and equipment” as an extension of themselves.

If humans continue doing this, half the plant and animal species on earth will be extinct well within 200 years. In fact, if the greenhouse effect is taken into consideration, this could happen within a few tens of years. We have come to the realization that the environmental problems caused by such irresponsible human behavior would greatly undermine both biological diversity and human survivability. This has given rise to the establishment and strengthening of regulatory controls ó consisting of technical standards and guidelines applicable to machines and licensing and certification systems applicable to people.

Meanwhile, technological innovations in recent years have been bringing “machinery and equipment” and “information and communication” together, leading to a new industrial revolution.

While “Production technologies” have so far single-mindedly pursued the “processing” of the earth's natural resources, this represents a gross bias towards “making things” and a negligence about the development of certain element technologies essential for the survival and prosperity of mankind contrary to the raison díÍtre of technology.

(1) Learning from nature

As the end of the 20th century draws near, many industries are confronted by environmental problems and are approaching a major turning point. Namely, industries are moving in the direction of reducing/eliminating waste generation, rather than heavily relying on treatment/disposal, as is the case at present. This trend is expected to accelerate in the 21st century, and will one day relieve industry, administrative agencies and even environmental organizations of dealing with waste collection, treatment and disposal ó tasks required at the end of the waste management cycle under current practice and at present strongly emphasized for pollution control reasons. To learn from nature, the concept of industrial ecology must be introduced by drawing an analogy from natural ecosystems.

In future, manufacturers will be required to incorporate waste disposal costs into production costs in industrialized countries and think hard about how to change production systems, products and raw materials to minimize overall costs.

(2) Nature's helping hand

Nobody would deny that human beings are nature's parasites, and it is also true that human productive activities and their growth rely heavily on energy use. We must therefore work hard to fast-forward the development of clean energy technologies, and use them to reduce air pollution caused by the mass consumption of energy, as well as making it an important breakthrough towards the resolution of global environmental problems such as global warming. Sunlight, which is available anywhere on earth, is a typical dispersed energy source, and, because of its low density nature, high efficiency use is essential.

(3) Technology is part of culture

Culture gives birth to different languages and different forms of music and literature. If so, there is no reason why there cannot be different forms of technology for different needs (in terms of areas, cultures and environmental requirements). For example, what about a technology in which human beings and machinery take care of qualitative (i.e. judgmental) and quantitative aspects of tasks, respectively? Such a technology would allow customer-preference, small-batch and flexible-production to be placed at the basis of production activities, as well as saving energy and resources. In fact, this type of system would respect and promote human skills, originality and creativity, society's greatest assets, and can therefore be called an anthropocentric system, a system that revolves around human needs. On this basis, it is necessary to develop a new industrial culture by adequately mobilizing technology and production capacity.

(4) “Four-in-one-type” technologies

Past technologies centered around “making things”. However, now is the time to go back to basics. Namely, in addition to the thing (what), technologies must also focus on the situation (where and when), conditions (why and how) and people (who).

10.1.2. Prediction about relationship between tools, information, energy, environment, living organisms and human beings

(1) Tools (implements and machinery)

From an overall degree of importance index viewpoint, hopes were pinned on the advent of intelligent material systems for the realization of new engineering endeavors, such as “08. Practical use of room temperature superconductors in industrial products” (degree of degree of importance index 88) and “10. Widespread use of high functionality materials and super materials based on atomic and molecular structure control”, (degree of importance index 81). Other topics of note were “05. Development of machine tools with constructions immune to thermal deformation” and “01. Radical change in the theories of designing artificial objects based on microtechnology” in terms of “contribution to socioeconomic development”.

(2) Information (electronics)

Hopes are pinned on flow-on effects of information (electronics) technology. Topics in point include: “18. Practical use of superprecision processing technologies capable of measurement to the angstrom order and femtosecond order”, in terms of overall importance (degree of importance index 81); “24: Technologies for direct machining from design data based on automation of machining process designing” and “26: Widespread use of decentralized manufacturing systems based on internationalization and networking”, in terms of “contribution to socioeconomic development”; “38: Widespread use of virtual reality communication systems that provide people with limited mobility with services that satisfy their everyday needs”, in terms of “response to people’s needs”; and “17: Beginning of impact of silicon microscopic structures control technology production and machinery area”, in terms of “expansion of human intellectual resources”.

(3) Energy

Hopes are pinned on topics including the following: “42: Widespread use of nonfossil energy sources in all areas of life including home, industry and transportation” (degree of importance index 94), and “44: Practical use of technologies that enable the direct storage of electricity” (degree of importance index 90); “45: Widespread use of industrial heat recovery systems based on thermoelectric devices”, “43: Practical use of bioreactor systems in solid waste treatment plants” and “46: Widespread use of automobiles and power engines that use hydrogen as fuel”, in terms of the “resolution of global scale problems”; and “41: Development of a space propulsion technology based on 'distortions in space' created by ultra-strong magnetic field generators”, in terms of “expansion of human intellectual resources”.

(4) Environment

Hopes are pinned on topics such as the following: “50: Widespread use of designing, producing, collecting and recycling systems which make it possible to recycle most used materials” (degree of importance index 92), “51: Widespread use of global environmental conservation measures based on carbon dioxide recovery technology etc. throughout the world” (degree of importance index 87), and “49: Widespread use of low entropy-generating eco-factories, which give due consideration to the impact on ecosystems” (degree of importance index 86) , in terms of overall importance; and “47: Development of a global warming countermeasure technology that involves the ejection of heat energy having accumulated on the earth's surface into outer space”, in terms of “resolution of global scale problems”.

(5) Living organisms

Hopes are pinned on topics such as the following: “55: Practical use of technologies for mass-producing hydrogen from organic substances through utilization of solar energy and biological systems” (degree of importance index 78), in terms of overall importance; and “52: Discovery of new laws, etc. relating to the functions of living organisms, leading to a radical change in the theories of designing artificial objects”, in terms of “expansion of human intellectual resources”.

(6) Human beings

Topics of particular note are “70: Widespread use of earthquake damage alleviation systems for industrial complexes, etc. based on the operation of safety devices in response to initial mild tremors” (degree of importance index 88), in terms of overall importance; “71: Widespread use of science museums capable of fostering scientific skills in children through play”, in terms of “expansion of human intellectual resources”; and “67: Widespread use of production systems that provide comprehensive support for senior citizens and people with disabilities”, in terms of “response to people’s needs”.

(Tadao Kawaguchi)

10.2. Forecast topic framework

In the course of compiling forecast topics, a framework representing the organization of technologies in tabulated matrix form was drawn up for each field, with objectives and technological domains defining the rows and columns of the table, respectively. The framework is designed to present an overall picture of technological development in each field in terms of future prospects, importance, etc. as seen from the present perspective, and is also used as a working framework for future reviews of forecast topics.

Table 10.2-1 Forecast Topic Framework for Production and Machinery Field

Domain / Relationship	Common foundation	Manufacturing systems (production)	Administration/distribution system (distribution)	Social/global systems (consumption)
Tools (implements and machinery)	01 02 03 04 05 06 07	08 09 10 11 12 13 14 15		16
Information (electronics)	17 18 19	20 21 22 23 24 25 26	27 28 29 30 31 32 33 34	35 36 37 38 39 40
Energy	41 42 43	44 45		46
Environment	47	48 49		50 51
Living organisms	52 53 54 55 56 57 58 59 60	61 62 63 64		
Human beings	65		64	67 68 69 70 71
		66		

* Topic 64 appears in two cells as two domain-relationship combinations apply to it.

* Figures appearing in the table represent topic numbers.

10.3. Topics with high degree of importance

Degree of importance index scores (Note 1) averaged at 64.5 for topics in the production and machinery field as a whole. Topics considered of particular importance to Japan (top 20 topics in terms of degree of importance index score) are listed in the table below. Notably, up to 9 topics featuring in the top 20 related to the environment and energy.

Table 10.3-1 Top 20 Topics in Terms of Degree of Importance Index

Topic	Degree of importance index	Forecasted realization time (year)
42 Widespread use of non-fossil energy sources (wind, geothermal, solar (photovoltaic/solar thermal) and waste heat) in all areas of life including household, industry and transportation.	94	2018
50 Widespread use of designing, producing, collecting and recycling systems which make it possible to recycle most used materials through legally establishing manufacturers' responsibilities for collection and disposal of disused products.	92	2012
44 Practical use of technologies that enable the direct storage of electricity (superconducting magnets, flywheels and capacitors).	90	2016
08 Practical use of room temperature superconductors in industrial products.	88	2016
70 Widespread use of earthquake damage alleviation systems for industrial complexes, nuclear facilities, etc. based on the early operation of safety devices in response to initial mild tremors.	88	2009

Topic	Degree of importance index	Forecasted realization time (year)
51 Advancements in technological development such as carbon dioxide recovery and detoxification of harmful wastes, leading to the widespread use of global environmental conservation measures throughout the world.	87	2018
49 Widespread use of low entropy-generating eco-factories, which give due consideration to the impact on local ecosystems throughout product life cycles, from manufacture to disposal.	86	2017
18 Practical use of superprecision processing technologies (machining, analysis and testing) through the availability of length, displacement and surface roughness measurement to the angstrom order and time measurement to the femtosecond order, as a result of advancements in beam technology, involving ions, electrons and lasers, and equipment control technology.	81	2009
10 Establishment of atomic and molecular structure control techniques, leading to widespread use of high functionality materials and super materials, designed to operate under extreme conditions.	81	2019
19 Radical changes to the production and machinery area through multimedia technology (interface between the analog world of human perception, characterized by visual and auditory senses, and the digital world of computers and other digitally operated artificial objects).	80	2006
17 Impact of engineering techniques that control silicon microscopic structures (to choose desired atomic and molecular arrangements at will) felt in all aspects of the production and machinery area.	78	2010
55 Practical use of technologies for mass-producing hydrogen by decomposing organic substances through application of solar energy and biological systems.	78	2021
43 Practical use of bioreactor systems in solid waste treatment plants.	77	2014
33 Strengthening of the relationship between consumption and production and advancements in networking between stores and factories, leading to widespread mergers between manufacturers and retailers/wholesalers and between manufacturers and distributors.	73	2007
15 Widespread use of ultrapure refining techniques not only in chemical engineering but also throughout the industry - in resource recovery, support, production efficiency improvements, etc.	73	2014
01 Discovery of a number of new laws, effects and phenomena through microtechniques, leading to a radical change in the theories of designing artificial objects.	73	2011
69 Widespread use of safety measures for industrial complexes, aircraft, tankers, large storage tanks, as suitable for their size and functionality, based on potential danger assessment and accident scenario prediction techniques.	73	2010
67 Widespread use of production systems that provide comprehensive support for senior citizens suffering from functional degeneration (cerebral and physical) and for people with disabilities.	73	2013
06 Widespread use of quick assembly and disassembly techniques which do not use bolt and nut joints.	71	2010
09 Practical use of liquid crystal polymers in electronics and information technology as materials that feature memory, archival and switching functions.	70	2009

Note 1: Degree of importance index = (number of “high” responses × 100 + number of “medium” responses × 50 + number of “low” responses × 25 + number of “unnecessary” responses × 0) ÷ total number of degree of importance responses

10.4. Forecasted realization times

Forecasted realization times were distributed as shown in the diagram below.

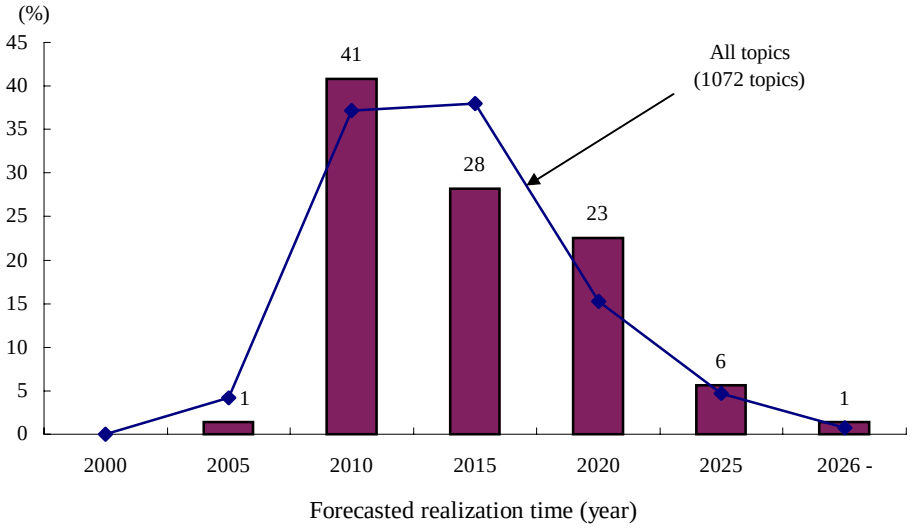
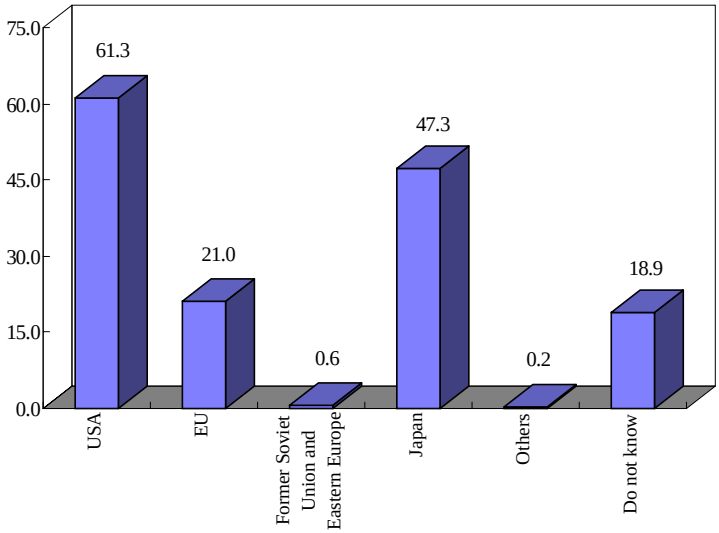


Fig. 10.4-1 Trends in Forecasted Realization Times

The distribution of forecasted realization times in this field peaked in the 2006-2010 period a little earlier than the general trend covering all topics, which saw its forecasted realization time distribution peaking in the 2011-2015 period. However, the distribution from 2016 onward was very similar.

10.5. Current leading countries etc.

Responses to the question concerning current leading countries etc. were as shown in the diagram below. Named by 61.3% of the respondents, the U.S. ranked No. 1 in this field, followed by Japan, which was 14% behind.



10.6. Comparison with the 5th Survey (previous survey)

Of the 71 topics included in the latest survey, 19 (27%) were identical to the previous survey, 13 (18%) were modified, and 39 (55%) were newly introduced. For identical topics, the results of the latest survey were compared with those of the previous survey in terms of degree of importance index scores and forecasted realization times, as shown in the table below.

Degree of importance index scores rose for 7 topics, remained the same for 1 topic and fell for 11 topics. “54: Practical use of technologies for producing glucide by artificial photosynthesis” saw the greatest jump, up 11 points, while “58: Development of high energy converting efficiency machines which apply the biological energy converting mechanism” saw the greatest drop, down 16 points.

From the 4th to the 5th Survey, forecasted realization times were pushed back for 13 of the 28 identical topics, brought forward for 6 topics and remained the same for 2 topics. In contrast, from the 5th to the 6th Survey, forecasted realization times were pushed back for all topics. “53: Development of technology to synthesize protein from carbon dioxide and ammonia, via a bioreactor” and “55: Practical use of technologies for mass-producing hydrogen from organic substances through application of solar energy and biological systems” saw their forecasted realization time pushed back most (15 years).

Table 10.6-1 Comparison with 5th Survey for Identical Topics

Topic	Importance index / forecasted realization time	
	6th survey	5th survey
02 Widespread use of intelligent materials which respond and adapt to external stimuli by changing their characteristics accordingly leading to the improvement of machine functions (e.g. shape memory alloys, piezoelectric ceramics, magnetostrictive materials, and electroviscous and magneto viscous fluids)	61/2007	52/2000
11 Realization of new material plants utilizing high-vacuum and weightless conditions in space.	52/2017	61/2008
24 Automation of most machining process designing jobs based on artificial intelligence techniques, leading to the widespread use of technologies for directly machining from design data.	66/2010	67/2004
27 Practical use of pocket-size voice actuated interpreting machines that enable people to communicate even if they do not speak each other's language.	64/2012	76/2008
28 Widespread use of automatic translation machines capable of rendering foreign-language documents into Japanese (or vice-versa) in offices.	66/2009	71/2003
37 Widespread use of operatorless systems enabling at-home health examination and diagnosis.	63/2011	52/2006
39 Development of home-use-robots that carry out chores such as vacuuming and clothes washing by learning their owners’ habits.	41/2014	38/2004
45 Widespread use of industrial heat recovery systems based on thermoelectric devices.	70/2016	69/2009
46 Widespread use of automobiles and power engines that use hydrogen as fuel instead of petroleum or alcohol.	68/2017	78/2009
50 Widespread use of designing, producing, collecting and recycling systems which make it possible to recycle most used materials through legally establishing manufacturers' responsibilities for collection and disposal of disused products.	92/2012	92/2004
51 Advancements in technological development such as carbon dioxide recovery and detoxification of harmful wastes, leading to the widespread use of global environmental conservation measures throughout the world.	87/2018	96/2011
53 Development of technology to synthesize protein from carbon dioxide and ammonia, via a bioreactor.	66/2018	73/2003
54 Practical use of technologies for producing glucide by artificial photosynthesis applying the mechanism of natural photosynthesis.	70/2019	59/2005
55 Practical use of technologies for mass-producing hydrogen by decomposing organic substances through application of solar energy and biological systems.	78/2021	74/2006

Topic	Importance index / forecasted realization time	
	6th survey	5th survey
56 Development of flexible actuators resembling human muscles, which can be applied to small, lightweight robots.	53/2013	68/2005
58 Development of high energy converting efficiency machines which apply the biological energy converting mechanism.	60/2021	76/2010
61 Practical use of basic chemical product manufacturing processes that utilize the efficiency of microorganisms living in extreme environmental conditions (e.g. ultra high pressure and high pH).	58/2014	59/2006
68 Practical use of “behavior alarm” systems based on elucidation of physical and psychological mechanisms that cause human error.	62/2014	68/2011
71 Spread of science museums capable of fostering scientific skills of children through play based on the applied use of natural history and science education techniques.	60/2007	53/2001

Note: Up until the 5th Survey, realization meant realization in Japan unless otherwise specified. However, this was changed to mean realization somewhere in the world in the 6th Survey. Therefore, care should be taken when comparing forecasted realization times from the two surveys.

Division	Topic serial No.	Topic	Questionnaire round	Number of respondents	Degree of expertise (%)			Importance (index, %)					Expected effect (%)				Forecasted realization time			Leading countries (%)						Measures the government should adopt (%)							Potential problems (%)			
					High	Medium	Low	Index	High	Medium	Low	Unnecessary	Socioeconomic development	Resolution of global problems	People's needs	Expansion of intellectual resources	2001 2006 2011 2016 2021 2026	Will not be realized (%)	Do not know (%)	USA	EU	Former Soviet Union and Eastern Europe	Japan	Other countries	Do not know	Foster human resources	Promote exchanges among industrial, academic and government sectors and different fields	Upgrade advanced facilities and equipment	Develop a research base	Increase government research funding	Adjust regulations (relax/toughen)	Others	Adverse effect on the natural environment	Adverse effect on safety	Adverse effect on morals, culture or society	Other adverse effects
Tools (implements and machinery)	1	Discovery of a number of new laws, effects and phenomena through microtechniques, leading to a radical change in the theories of designing artificial objects.	1	115	15	34	51	73	52	35	13	0	67	21	33	59		2	11	77	24	1	58	2	15	53	49	35	5	50	3	2	14	13	12	1
			2	90	12	29	59	73	52	38	10	0	69	13	36	62		0	4	78	17	0	54	1	13	59	50	34	1	49	1	0	12	13	13	0
			X	11	100	0	0	91	82	18	0	0	73	36	45	73		0	0	82	45	0	73	9	0	73	64	36	0	55	0	0	9	9	9	0
	2	Widespread use of intelligent materials which respond and adapt to external stimuli by changing their characteristics accordingly leading to the improvement of machine functions (e.g. shape memory alloys, piezoelectric ceramics, magnetostrictive materials, and electroviscous and magneto viscous fluids)	1	129	11	36	53	62	32	51	17	0	81	19	38	12		0	5	64	26	2	59	0	22	41	64	29	6	31	3	1	10	12	4	2
			2	104	9	33	59	61	26	66	8	0	81	15	38	3		0	2	70	16	0	62	0	17	38	72	24	3	35	1	0	10	13	0	1
			X	9	100	0	0	89	78	22	0	0	100	22	33	0		0	0	100	11	0	67	0	0	22	78	33	11	56	0	0	22	11	0	0
	3	Widespread use of hard coatings generated via the complex-shape diamond thin-film production technique in sliding surfaces of bearings, special tools, etc.	1	107	13	37	50	54	22	51	26	1	84	21	9	7		0	5	47	23	8	60	0	19	31	53	32	4	30	3	0	11	7	1	4
			2	90	12	39	49	52	10	78	12	0	90	12	7	1		0	3	48	14	4	76	0	19	27	69	29	1	29	1	1	10	6	0	3
			X	11	100	0	0	55	9	91	0	0	91	0	9	9		0	0	64	27	0	100	0	0	27	82	18	0	45	0	0	9	18	0	9
	4	Development of friction surface control techniques (electrical, contact angle and air resistance) through elucidation of friction generation mechanisms.	1	109	12	42	46	57	25	55	19	1	70	38	10	36		4	10	42	39	2	45	0	33	52	42	36	2	35	1	1	9	4	0	4
			2	86	10	44	45	56	18	70	12	0	81	28	6	30		0	5	48	38	1	50	0	31	64	45	36	0	37	0	0	6	3	0	2
			X	9	100	0	0	72	56	22	22	0	78	44	11	33		0	0	67	56	0	89	0	0	67	11	22	0	56	0	0	11	0	0	0
	5	Development of machine tools with constructions immune to thermal deformation.	1	117	29	28	43	64	37	47	14	2	88	13	9	10		9	11	30	42	2	63	1	20	37	54	24	3	44	1	1	9	4	2	3
			2	98	27	36	38	66	37	53	10	0	95	9	4	5		4	7	28	47	1	69	1	17	38	65	18	1	46	0	0	6	4	1	2
			X	26	100	0	0	82	65	31	4	0	96	19	4	4		4	4	19	50	0	96	4	4	42	69	15	0	58	0	0	12	0	0	8
	6	Widespread use of quick assembly and disassembly techniques which do not use bolt and nut joints.	1	114	18	34	47	66	42	40	16	2	82	22	19	8		9	14	32	23	1	38	0	42	37	48	18	4	27	5	1	11	7	4	4
			2	95	16	33	52	71	46	46	9	0	83	19	12	3		8	6	35	19	0	46	0	40	42	56	12	1	25	3	0	12	8	1	1
			X	15	100	0	0	77	57	36	7	0	67	27	20	7		13	0	40	20	0	53	0	27	40	33	7	0	27	7	0	7	13	7	7
	7	Practical use of metal attachment and metal growth methods in metal processing, replacing current metal removal method.	1	112	25	30	45	63	34	49	16	1	90	31	6	17		4	7	47	27	4	48	0	23	41	54	31	2	35	1	0	13	4	1	3
			2	99	22	36	41	65	32	63	5	0	92	21	4	5		1	4	62	20	2	61	0	14	47	64	27	0	34	1	0	15	4	0	1
			X	22	100	0	0	75	55	36	9	0	95	18	5	9		5	0	64	23	5	77	0	0	68	59	18	0	50	0	0	18	0	0	5
	8	Practical use of room temperature superconductors in industrial products.	1	99	4	16	80	82	67	29	4	0	78	71	10	28		4	12	61	38	5	59	1	23	55	45	30	11	58	2	0	13	7	3	1
			2	88	2	15	83	88	77	22	1	0	82	70	3	19		2	8	67	33	2	69	1	18	59	42	30	2	67	1	0	14	8	0	1
			X	2	100	0	0	100	100	0	0	0	50	100	0	50		0	0	100	50	0	50	0	0	100	0	50	0	100	0	0	0	50	0	0
	9	Practical use of liquid crystal polymers in electronics and information technology as materials that feature memory, archival and switching functions.	1	56	5	23	71	70	47	40	11	2	89	20	21	13		0	2	52	16	0	73	0	11	38	54	25	5	43	0	0	11	11	4	2
			2	54	0	19	81	70	46	43	11	0	91	9	19	2		0	2	57	6	0	80	0	13	37	69	15	0	46	0	0	7	13	2	2
			X	0	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10	Establishment of atomic and molecular structure control techniques, leading to widespread use of high functionality materials and super materials, designed to operate under extreme conditions.	1	87	5	22	74	79	60	35	5	0	80	22	15	49		3	13	68	29	1	52	0	21	55	43	45	6	59	2	0	13	7	1	3
			2	76	0	13	87	81	64	32	4	0	88	7	5	41		1	8	75	17	0	49	0	16	61	39	41	3	64	1	0	16	9	1	1
			X	0	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

(Note) See page 7 for the interpretation of the graphs.

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Division	Topic serial No.	Topic	Questionnaire round	Number of respondents	Degree of expertise (%)			Importance (index, %)					Expected effect (%)				Forecasted realization time			Leading countries (%)						Measures the government should adopt (%)							Potential problems (%)			
					High	Medium	Low	Index	High	Medium	Low	Unnecessary	Socioeconomic development	Resolution of global problems	People's needs	Expansion of intellectual resources	2001 2006 2011 2016 2021 2026	Will not be realized (%)	Do not know (%)	USA	EU	Former Soviet Union and Eastern Europe	Japan	Other countries	Do not know	Foster human resources	Promote exchanges among industrial, academic and government sectors and different fields	Upgrade advanced facilities and equipment	Develop a research base	Increase government research funding	Adjust regulations (relax/toughen)	Others	Adverse effect on the natural environment	Adverse effect on safety	Adverse effect on morals, culture or society	Other adverse effects
Tools (implements and machinery)	11	Realization of new material plants utilizing high-vacuum and weightless conditions in space.	1	104	4	11	86	58	31	42	24	3	70	30	3	59		8	8	92	18	14	21	0	5	38	22	38	5	60	2	0	18	9	7	3
			2	92	1	13	86	52	18	58	22	2	71	20	2	62		5	9	90	14	9	23	0	7	36	17	39	1	70	1	1	26	8	2	0
			X	1	100	0	0	25	0	0	100	0	100	0	0	100		0	0	100	100	0	100	0	0	100	100	100	0	0	0	0	0	100	0	0
	12	Development of artificial high performance catalysts enabling the manufacture of basic chemical products at near normal temperature and pressure conditions.	1	32	0	28	72	65	37	57	0	7	56	59	3	16		3	6	69	47	3	34	0	19	41	28	28	22	34	3	0	31	6	0	0
			2	26	0	15	85	63	27	73	0	0	69	65	0	0		0	8	73	42	0	19	0	19	46	35	27	8	46	8	0	35	0	0	0
			X	0	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	13	Widespread use of remote maintenance of equipment and facilities with advanced and multiple functions - to be carried out from outside the plant.	1	154	22	31	47	58	26	54	18	2	78	18	42	5		3	8	61	14	0	68	0	17	33	51	19	1	32	17	1	3	32	11	3
			2	131	21	31	49	58	22	65	12	2	82	14	41	2		2	6	63	8	0	69	0	14	34	66	15	1	37	13	1	2	43	10	2
			X	27	100	0	0	68	41	52	4	4	78	22	26	0		11	0	67	4	0	74	0	4	41	63	15	4	37	19	0	0	37	11	7
	14	Development of maintenance robots capable of diagnosing and repairing machinery and equipment previously carried out by humans.	1	161	22	32	46	60	31	48	18	3	74	12	49	4		4	7	57	18	0	73	1	10	37	55	18	2	34	11	1	1	28	14	1
			2	137	22	30	48	62	30	57	12	1	82	7	45	4		3	4	62	13	0	82	0	5	36	72	11	1	38	7	0	0	40	10	1
			X	30	100	0	0	70	50	33	13	3	83	3	37	10		7	0	50	20	0	87	0	0	50	67	7	3	43	10	0	0	43	17	3
	15	Widespread use of ultrapure refining techniques not only in chemical engineering but also throughout the industry - in resource recovery, support, production efficiency improvements, etc.	1	57	7	21	72	71	51	35	12	2	65	79	9	11		0	5	42	56	0	46	0	23	35	42	26	9	46	9	0	39	5	5	0
			2	45	4	16	80	73	51	40	9	0	53	80	7	4		0	0	44	58	0	44	0	22	40	56	11	2	56	9	0	40	0	2	0
			X	2	100	0	0	100	100	0	0	0	100	100	50	0		0	0	50	50	0	50	0	50	0	100	50	0	50	50	0	50	0	0	0
	16	Widespread use of mega-space structures that make all-weather, 24-hour-a-day life-styles possible, including leisure activities.	1	85	1	6	93	34	6	27	56	11	58	7	54	1		4	7	59	5	2	41	0	22	7	19	7	0	8	33	4	25	24	25	1
			2	71	1	6	93	32	3	27	63	7	63	1	62	0		3	4	65	4	1	48	0	18	10	25	3	0	4	51	7	34	21	38	1
			X	1	100	0	0	50	0	100	0	0	0	0	100	0		0	0	100	0	0	0	0	0	0	0	0	0	0	100	0	0	0	100	0
Information (electronics)	17	Impact of engineering techniques that control silicon microscopic structures (to choose desired atomic and molecular arrangements at will) felt in all aspects of the production and machinery area.	1	77	9	26	65	77	58	38	3	1	87	16	10	45		0	5	82	30	0	66	1	6	57	31	35	6	52	1	0	8	3	4	5
			2	67	4	22	73	78	59	38	2	2	87	4	6	52		0	3	93	25	0	63	0	3	75	28	36	0	64	0	1	9	6	1	1
			X	3	100	0	0	83	67	33	0	0	100	0	0	67		0	0	100	33	0	67	0	0	100	33	33	0	100	0	0	0	33	0	0
	18	Practical use of superprecision processing technologies (machining, analysis and testing) through the availability of length, displacement and surface roughness measurement to the angstrom order and time measurement to the femtosecond order, as a result of advancements in beam technology, involving ions, electrons and lasers, and equipment control technology.	1	125	18	29	53	76	56	37	6	1	96	10	10	30		1	2	78	40	1	74	0	8	50	39	44	4	48	2	0	5	6	2	2
			2	104	12	33	56	81	64	33	3	0	96	5	7	25		0	3	86	35	0	76	0	4	59	40	42	1	52	0	0	4	6	1	1
			X	12	100	0	0	96	92	8	0	0	92	17	8	25		0	0	92	58	0	92	0	0	67	17	42	0	75	0	0	0	8	8	0
	19	Radical changes to the production and machinery area through multimedia technology (interface between the analog world of human perception, characterized by visual and auditory senses, and the digital world of computers and other digitally operated artificial objects).	1	154	19	32	48	74	53	39	7	1	90	11	55	16		0	3	90	19	1	47	1	5	45	51	23	5	39	20	1	3	28	27	3
			2	129	17	34	49	80	61	36	3	0	91	5	53	6		0	1	95	16	1	48	1	2	47	61	19	3	36	19	0	1	33	29	1
			X	22	100	0	0	86	73	27	0	0	95	9	55	5		0	0	95	14	0	36	0	0	41	68	14	5	41	36	0	0	36	27	0
	20	Practical use of the operation via keyboardless input devices (voice, gaze and electroencephalogram) of computerized manufacturing systems.	1	153	10	33	58	58	28	49	21	2	73	3	69	7		1	2	78	19	1	51	0	15	41	52	24	3	37	8	1	1	24	18	2
			2	135	7	30	63	57	21	64	14	1	75	1	74	1		1	1	86	10	1	55	0	10	41	63	19	1	39	4	0	0	36	20	1
			X	10	100	0	0	80	70	10	20	0	80	0	60	0		0	0	80	20	0	50	0	10	40	40	0	0	50	0	0	0	30	10	0

(Note) See page 7 for the interpretation of the graphs.

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Information (electronics)	21	Widespread use of systems capable of automatically indexing printed documents in databases and searching for them through advancements in pattern recognition technology.	1	143	6	29	65	62	33	50	16	1	82	3	50	11		1	2	72	13	1	52	1	15	34	46	17	13	24	11	1	0	22	25	2
			2	122	5	27	68	62	29	61	11	0	89	1	61	5		0	2	84	7	0	60	0	7	37	59	11	7	25	9	1	0	19	33	0
			X	6	100	0	0	63	33	50	17	0	83	0	50	17		0	0	67	0	0	67	0	0	33	50	0	17	33	0	0	0	0	0	0
	22	Widespread use of massive systems formed through the networking of machines and devices and evolving structure systems, superior in flexibility, security and maintainability.	1	123	16	33	51	64	38	43	16	3	85	13	31	12		2	4	72	15	0	40	0	13	41	42	23	4	37	14	2	7	27	20	2
			2	102	15	32	53	64	35	53	11	1	90	7	28	8		1	2	78	10	0	42	0	15	50	53	21	1	39	10	1	3	36	20	1
			X	15	100	0	0	78	60	33	7	0	100	13	33	20		0	7	73	20	0	60	0	7	53	53	7	0	40	13	0	7	20	27	7
	23	Establishment of a technology capable of measuring human sensations (e.g. five senses, stress and comfort level) and widespread use of products designed and manufactured based on it.	1	119	15	29	56	64	37	45	16	2	59	3	74	23		7	3	44	25	0	40	3	30	45	41	12	9	35	6	1	1	18	18	3
			2	105	13	28	59	63	32	59	10	0	62	0	83	13		2	4	55	20	0	52	2	25	54	52	10	4	44	3	0	0	19	22	0
			X	14	100	0	0	89	79	21	0	0	50	0	86	29		0	7	50	29	0	57	0	21	57	50	14	7	79	0	0	0	14	21	0
	24	Automation of most machining process designing jobs based on artificial intelligence techniques, leading to the widespread use of technologies for directly machining from design data.	1	162	27	32	41	66	39	47	14	1	89	6	20	10		6	2	65	27	2	69	0	8	44	54	17	7	26	4	2	2	10	12	3
			2	137	25	32	43	66	36	54	9	0	95	1	14	6		4	1	69	23	1	72	0	7	49	66	12	2	28	2	1	1	12	12	1
			X	34	100	0	0	78	59	35	6	0	97	3	18	12		0	3	82	38	0	88	0	0	65	68	21	3	32	3	3	3	12	15	3
	25	Practical use of virtual manufacturing systems that support manufacturing activities, including modeling, designing, production, operation (including maintenance), and waste disposal (e.g. by achieving optimization and efficiency improvements, and making application for approval/permission easier).	1	154	23	32	45	64	37	47	14	2	87	28	26	10		3	6	73	21	1	40	1	12	42	55	17	6	37	16	3	6	13	12	3
			2	127	20	29	50	62	30	60	9	2	91	19	20	5		3	6	83	15	0	40	0	9	45	70	12	3	36	10	2	2	17	13	2
			X	26	100	0	0	80	62	35	4	0	92	23	8	12		4	4	88	19	0	58	0	4	54	77	12	4	46	12	4	0	27	15	4
	26	Widespread use of decentralized manufacturing systems (through functional distribution along the lines of clients, providers and manufacturers) based on internationalization and networking.	1	135	22	25	53	68	43	46	10	2	87	24	17	3		2	7	77	21	1	41	0	11	27	53	12	6	30	28	3	3	16	21	4
			2	111	21	25	54	70	43	53	5	0	93	22	8	1		2	3	85	18	0	46	0	6	24	71	2	2	33	28	2	1	17	26	0
			X	23	100	0	0	89	78	22	0	0	91	26	9	4		0	0	96	30	0	43	0	0	35	83	0	0	35	22	4	0	13	22	0
	27	Practical use of pocket-size voice actuated interpreting machines that enable people to communicate even if they do not speak each other's language.	1	113	2	16	82	65	39	43	17	1	58	12	71	15		3	2	48	12	0	58	1	22	40	35	17	5	36	9	3	1	7	19	3
			2	103	1	17	83	64	34	53	13	0	63	5	81	9		3	1	48	9	0	72	0	16	57	46	8	2	43	5	2	0	5	27	1
			X	1	100	0	0	100	100	0	0	0	0	0	100	0		0	0	0	0	0	100	0	0	100	100	0	0	0	0	0	0	100	0	0
	28	Widespread use of automatic translation machines capable of rendering foreign-language documents into Japanese (or vice-versa) in offices.	1	125	2	16	82	65	39	45	15	1	74	5	46	16		1	2	37	10	1	65	1	17	44	39	14	9	29	5	2	1	4	18	2
			2	110	1	15	84	66	38	52	10	0	83	2	56	6		1	2	30	7	1	85	0	11	57	47	9	4	35	3	0	0	3	22	0
			X	1	100	0	0	100	100	0	0	0	0	0	100	0		0	0	0	0	0	100	0	0	0	100	100	0	100	0	0	0	100	100	0
	29	Widespread use of teleconferencing systems in offices.	1	148	5	24	71	49	17	47	32	3	73	15	39	8		3	1	72	20	1	50	1	11	16	21	14	2	15	28	5	0	22	17	2
			2	123	4	22	74	48	12	58	27	3	82	9	39	4		2	1	79	13	0	52	0	11	14	24	11	1	8	41	6	0	24	18	0
			X	5	100	0	0	70	40	60	0	0	100	20	0	0		0	0	80	0	0	80	0	0	20	0	40	0	20	60	0	0	20	60	0
	30	Widespread use of 100% paperless operation in offices.	1	151	5	23	73	47	18	39	38	6	53	55	14	2		40	5	64	17	1	25	1	17	13	17	9	4	11	26	6	3	21	22	1
			2	129	4	19	77	46	14	43	39	3	53	64	9	0		40	4	78	13	0	26	0	12	11	22	4	2	8	47	4	2	21	24	0
			X	5	100	0	0	65	40	40	20	0	40	80	0	0		60	0	60	20	0	0	0	0	20	0	0	0	20	40	0	0	40	20	0

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Information (electronics)	31	Widespread use of interactive AI systems that help people create ideas by offering useful triggers and contexts.	1	86	6	26	69	48	19	40	40	2	59	3	27	49		13	6	73	10	1	26	0	16	49	30	12	9	29	2	1	0	15	17	2
			2	77	5	18	77	46	13	46	41	0	60	3	29	42		9	5	83	9	0	23	0	13	64	35	6	3	32	3	1	0	13	22	0
			X	4	100	0	0	63	50	0	50	0	100	0	25	25		25	0	100	50	0	25	0	0	50	25	25	0	0	0	0	0	0	25	0
	32	Practical use of operation via keyboardless input devices (voice, gaze and electroencephalogram) of computerized office/distribution systems.	1	119	5	27	68	52	21	45	34	1	71	4	71	8		3	4	71	12	0	45	1	13	46	34	14	8	29	8	0	1	24	18	2
			2	104	2	26	72	48	11	59	29	1	71	1	81	2		1	5	84	7	0	43	0	11	61	43	9	5	30	4	0	0	32	15	0
			X	2	100	0	0	63	50	0	50	0	100	0	50	0		0	0	50	50	0	50	0	50	50	0	0	0	100	0	0	0	50	50	0
	33	Strengthening of the relationship between consumption and production and advancements in networking between stores and factories, leading to widespread mergers between manufacturers and retailers/wholesalers and between manufacturers and distributors.	1	129	12	26	61	72	46	49	5	0	92	13	40	2		3	2	79	17	1	50	1	11	11	36	9	5	13	50	2	1	19	19	1
			2	107	7	24	68	73	47	52	1	0	94	7	43	1		1	0	85	13	0	54	0	6	8	50	3	2	7	71	0	0	19	22	0
			X	8	100	0	0	81	63	38	0	0	100	25	13	0		0	0	100	0	0	38	0	0	13	50	0	0	13	63	0	0	25	38	0
	34	Practical use of home electronic ordering systems that allow customers to design their own products (e.g. a car to one's taste) on a global scale.	1	120	10	23	67	51	22	40	34	4	77	4	53	3		7	9	68	14	1	34	1	16	13	28	4	5	8	38	3	3	20	18	1
			2	107	7	23	70	47	13	52	31	4	74	0	68	1		5	4	79	6	0	38	0	13	9	36	1	2	5	57	2	2	26	21	0
			X	7	100	0	0	61	29	57	14	0	71	0	57	0		0	0	100	14	0	14	0	0	0	14	0	0	0	43	0	0	71	14	0
	35	Widespread use of telecommuting via multimedia information exchange tools (e.g. e-mail, teleconferencing and WWW) based on the Internet and intranets, except where face-to-face meetings are essential.	1	158	8	23	69	51	21	45	32	3	70	18	72	7		8	6	81	22	1	25	0	9	15	25	10	2	15	42	5	0	27	43	1
			2	134	5	22	72	49	15	53	30	2	72	11	81	3		4	4	87	14	0	21	0	7	15	28	5	1	12	64	2	0	19	49	1
			X	7	100	0	0	68	43	43	14	0	57	0	86	0		0	0	86	14	0	0	0	14	0	14	0	0	29	71	0	0	29	71	0
	36	Spread of network-centered life-styles (via one or more computers per person).	1	160	9	26	65	57	27	47	24	2	79	11	74	11		4	3	88	21	1	30	0	5	16	18	9	8	9	34	4	1	29	34	2
			2	135	6	22	72	54	19	59	20	2	82	1	86	4		5	1	91	16	0	30	0	4	15	24	5	2	7	56	1	0	30	45	0
			X	8	100	0	0	78	63	25	13	0	63	0	100	0		0	0	100	25	0	25	0	0	0	25	0	0	38	50	0	0	38	75	0
	37	Widespread use of operatorless systems enabling at-home health examination and diagnosis.	1	106	5	19	76	62	36	44	18	2	42	3	94	0		6	4	52	17	0	23	3	32	17	32	8	10	28	42	1	0	44	22	2
			2	91	3	13	84	63	33	55	10	2	43	0	96	0		2	3	66	18	0	24	1	23	13	37	4	3	30	59	0	0	49	20	0
			X	3	100	0	0	100	100	0	0	0	33	0	100	0		0	0	67	33	0	0	0	0	0	33	0	0	67	33	0	0	0	33	0
	38	Widespread use of virtual reality communication systems that provide people with limited mobility with services that satisfy their everyday needs (e.g. entertainment, welfare and medical care).	1	107	7	19	75	53	23	46	29	2	43	3	94	2		3	7	63	20	2	26	1	21	26	28	14	6	27	29	2	0	32	28	1
			2	89	4	18	78	49	11	63	22	3	35	0	94	1		1	2	71	13	0	24	1	17	26	42	2	1	28	44	0	0	43	35	0
			X	4	100	0	0	63	25	75	0	0	50	0	100	25		0	0	75	0	0	25	0	0	25	25	0	0	50	50	0	0	0	50	0
	39	Development of home-use-robots that carry out chores such as vacuuming and clothes washing by learning their owners' habits.	1	123	15	24	61	44	15	39	38	8	45	2	89	2		11	5	46	8	1	51	1	21	30	37	9	2	22	9	2	1	19	26	1
			2	101	16	22	62	41	10	42	39	8	43	0	90	1		12	1	50	2	0	70	0	16	39	52	2	0	28	5	1	0	22	29	0
			X	16	100	0	0	69	50	31	13	6	50	0	94	6		6	0	56	6	0	88	0	0	50	50	0	0	38	6	0	0	25	31	0
	40	Practical use of new home electronics products which offer more features than mere information processing and data accumulation (e.g. ultra-small mass spectrograph and prescription drug dispenser (home microfactory)) via the integration of micromachine technology and sensor technology with electronic circuit technology.	1	84	19	19	62	51	24	39	31	6	65	13	74	7		11	6	45	19	0	43	2	29	42	35	20	6	32	13	1	1	26	13	2
			2	76	14	17	68	48	19	41	35	5	67	5	87	3		5	3	50	17	0	57	1	25	55	43	14	1	36	8	1	0	36	14	0
			X	11	100	0	0	70	55	27	9	9	64	9	82	9		9	0	64	36	0	55	9	18	55	27	27	0	64	0	0	0	27	0	0

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Energy	41	Development of a space propulsion technology based on "distortions in space" created by ultra-strong magnetic field generators (stronger than 1 billion T).	1	27	11	19	70	56	27	46	23	4	56	33	11	59		11	22	52	19	7	26	0	19	26	22	41	4	52	4	0	37	22	7	4
			2	21	5	10	86	55	19	62	19	0	67	19	5	57		19	10	57	14	10	29	0	19	29	5	29	0	62	5	5	52	19	5	5
			X	1	100	0	0	100	100	0	0	0	0	0	0	100		0	0	100	100	0	100	0	0	100	0	100	0	100	0	0	0	0	0	0
	42	Widespread use of non-fossil energy sources (wind, geothermal, solar (photovoltaic/solar thermal) and waste heat) in all areas of life including household, industry and transportation.	1	114	7	19	74	85	75	18	7	0	56	96	18	5		4	11	60	39	3	49	1	17	37	39	18	3	63	23	0	32	5	1	3
			2	93	5	15	80	94	89	8	3	0	57	98	12	1		1	10	71	38	0	48	0	13	32	34	8	0	74	18	0	40	2	0	1
			X	5	100	0	0	90	80	20	0	0	40	100	0	0		0	0	60	40	0	60	0	20	0	20	0	0	80	40	0	40	0	0	0
	43	Practical use of bioreactor systems in solid waste treatment plants	1	56	5	21	73	76	56	41	2	2	36	95	16	0		2	0	34	29	0	48	0	29	29	45	16	13	55	23	0	21	4	4	2
			2	43	2	19	79	77	53	47	0	0	30	95	9	0		2	0	42	30	0	63	0	21	21	56	0	5	77	23	0	30	2	0	0
			X	1	100	0	0	100	100	0	0	0	0	100	0	0		0	0	100	100	0	100	0	0	100	0	0	100	100	0	0	0	0	0	0
	44	Practical use of technologies that enable the direct storage of electricity (superconducting magnets, flywheels and capacitors).	1	105	7	19	74	84	69	28	2	1	52	95	9	4		5	10	52	30	2	41	0	30	43	37	26	2	61	13	0	17	11	1	4
			2	84	8	18	74	90	81	18	1	0	56	94	7	1		5	6	63	26	0	50	0	24	54	33	15	0	71	10	0	24	8	0	0
			X	7	100	0	0	93	86	14	0	0	86	100	0	0		0	14	86	43	0	100	0	0	71	43	29	0	100	14	0	0	0	0	0
	45	Widespread use of industrial heat recovery systems based on thermoelectric devices.	1	68	4	25	71	65	40	41	19	0	32	99	4	3		7	9	32	18	1	35	0	41	35	40	19	1	51	15	0	13	7	0	3
			2	59	5	24	71	70	44	49	7	0	31	98	0	2		2	10	41	14	0	44	0	37	37	49	7	0	66	8	0	14	5	0	0
			X	3	100	0	0	42	0	67	33	0	0	100	0	0		0	0	67	0	0	67	0	0	67	33	0	0	67	0	0	0	33	0	0
	46	Widespread use of automobiles and power engines that use hydrogen as fuel instead of petroleum or alcohol.	1	109	7	21	72	67	42	43	12	3	42	92	7	2		11	13	49	36	4	54	3	23	33	42	17	3	45	24	0	20	20	2	2
			2	93	8	18	74	68	42	49	7	2	46	95	3	0		6	9	54	33	0	70	0	16	38	48	4	0	62	23	1	24	26	1	1
			X	7	100	0	0	93	86	14	0	0	29	100	0	0		0	0	86	71	0	86	0	0	57	57	0	0	71	14	0	29	29	0	0
Environment	47	Development of a global warming countermeasure technology (sky radiator) that involves the ejection of heat energy (radiation wavelengths of 8 - 13 microns) having accumulated on the earth's surface into the outer space.	1	37	8	11	81	60	38	32	24	5	14	92	0	11		16	27	35	14	0	19	0	46	38	22	14	3	46	5	0	30	3	0	0
			2	30	7	10	83	70	45	45	10	0	10	100	0	3		20	13	43	10	0	17	0	43	37	23	0	0	60	10	0	30	7	0	0
			X	2	100	0	0	100	100	0	0	0	0	100	0	0		0	0	100	50	0	50	0	0	100	50	0	0	100	0	0	50	0	0	0
	48	Practical use of a widely-applicable low noise technology, leading to its application in various manufacturing machines.	1	107	14	21	64	56	23	54	22	0	49	36	64	2		4	13	22	23	0	49	0	36	33	36	21	0	33	12	0	11	11	2	2
			2	89	11	21	67	53	16	65	19	0	45	31	73	0		3	4	17	15	0	60	0	31	30	57	12	0	35	8	0	12	10	1	0
			X	10	100	0	0	55	20	60	20	0	30	10	90	0		0	0	30	30	0	100	0	0	50	70	20	0	40	10	0	20	10	0	0
	49	Widespread use of low entropy-generating eco-factories, which give due consideration to the impact on local ecosystems throughout product life cycles, from manufacture to disposal.	1	103	15	16	70	83	69	24	6	0	44	95	17	6		3	12	26	61	0	35	1	21	38	51	18	3	56	24	1	26	3	5	2
			2	90	10	16	74	86	73	26	1	0	34	98	11	1		1	8	26	68	0	42	0	16	38	61	10	0	67	19	1	36	1	2	0
			X	9	100	0	0	100	100	0	0	0	33	100	0	0		0	0	22	89	0	44	0	0	44	44	0	0	67	11	0	22	0	0	0
	50	Widespread use of designing, producing, collecting and recycling systems which make it possible to recycle most used materials through legally establishing manufacturers' responsibilities for collection and disposal of disused products.	1	138	11	21	68	85	70	29	1	0	48	95	17	2		5	8	30	70	1	36	0	12	30	39	14	4	46	45	1	25	3	9	1
			2	111	10	14	76	92	85	15	0	0	40	99	10	1		4	6	20	84	0	33	0	9	28	50	6	1	56	56	0	30	2	5	0
			X	11	100	0	0	86	73	27	0	0	45	100	9	9		0	0	0	100	0	18	0	0	36	64	0	0	55	36	0	27	0	9	0

(Note) See page 7 for the interpretation of the graphs.

Division	Topic serial No.	Topic	Questionnaire round	Number of respondents	Degree of expertise (%)			Importance (index, %)					Expected effect (%)				Forecasted realization time			Leading countries (%)						Measures the government should adopt (%)							Potential problems (%)			
					High	Medium	Low	Index	High	Medium	Low	Unnecessary	Socioeconomic development	Resolution of global problems	People's needs	Expansion of intellectual resources	2001 2006 2011 2016 2021 2026	Will not be realized (%)	Do not know (%)	USA	EU	Former Soviet Union and Eastern Europe	Japan	Other countries	Do not know	Foster human resources	Promote exchanges among industrial, academic and government sectors and different fields	Upgrade advanced facilities and equipment	Develop a research base	Increase government research funding	Adjust regulations (relax/toughen)	Others	Adverse effect on the natural environment	Adverse effect on safety	Adverse effect on morals, culture or society	Other adverse effects
Environment	51	Advancements in technological development such as carbon dioxide recovery and detoxification of harmful wastes, leading to the widespread use of global environmental conservation measures throughout the world.	1	88	9	22	69	84	72	21	6	1	33	98	14	2		7	11	48	55	1	47	1	23	49	33	25	1	58	27	2	18	6	6	2
			2	77	8	22	70	87	75	24	0	1	25	95	8	1		4	14	47	69	0	47	0	17	53	27	14	0	74	21	0	23	4	1	0
			X	6	100	0	0	100	100	0	0	0	33	100	17	0		0	33	83	100	0	83	0	0	67	67	17	0	83	17	0	17	0	0	0
Living organisms	52	Discovery of new laws, effects and phenomena based on the functions of living organisms, leading to a radical change in the theories of designing artificial objects.	1	82	7	27	66	68	44	42	14	0	62	26	18	78		0	22	54	24	4	29	0	29	62	37	15	10	48	5	0	10	6	16	1
			2	67	7	25	67	65	38	47	15	0	66	18	15	79		0	18	58	18	1	30	0	30	75	31	10	4	46	1	1	6	7	16	0
			X	5	100	0	0	90	80	20	0	0	80	40	40	60		0	0	0	20	0	20	0	20	20	20	0	0	40	0	0	0	0	0	0
	53	Development of technology to synthesize protein from carbon dioxide and ammonia, via a bioreactor.	1	26	0	19	81	66	38	50	13	0	31	85	8	35		4	8	42	12	4	15	0	46	38	23	15	15	65	8	0	19	12	4	0
			2	22	0	27	73	66	36	55	9	0	27	86	0	32		5	5	41	9	0	14	0	55	36	18	18	14	73	5	0	23	14	5	0
			X	0	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	54	Practical use of technologies for producing glucide by artificial photosynthesis applying the mechanism of natural photosynthesis.	1	25	0	20	80	65	36	52	12	0	40	80	16	32		0	8	52	16	8	20	0	40	36	20	20	20	60	8	0	20	4	0	0
			2	21	0	19	81	70	48	38	14	0	33	81	0	33		0	14	43	10	0	19	0	48	48	14	14	19	71	5	0	24	5	0	0
			X	0	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	55	Practical use of technologies for mass-producing hydrogen by decomposing organic substances through application of solar energy and biological systems.	1	38	0	18	82	72	49	41	11	0	37	95	5	18		3	11	37	26	5	37	0	39	45	21	24	18	63	5	0	11	11	0	3
			2	33	0	15	85	78	58	39	3	0	33	91	0	9		3	12	33	21	0	39	0	45	48	15	18	9	67	0	0	12	9	0	3
			X	0	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	56	Development of flexible actuators resembling human muscles, which can be applied to small, lightweight robots.	1	101	19	21	60	55	21	54	24	0	74	4	77	14		5	8	61	25	2	60	0	18	48	46	21	6	51	3	0	1	9	10	2
			2	91	20	11	69	53	14	67	19	0	79	2	77	8		1	4	68	22	1	70	0	13	54	49	13	3	57	2	0	3	9	10	1
			X	18	100	0	0	67	39	50	11	0	72	0	83	22		6	0	67	33	0	94	0	0	56	44	6	0	78	6	0	0	6	17	0
	57	Widespread use of computer programs that automatically improve their own functionality through learning - by imitating the functions of living organisms.	1	88	15	24	61	55	20	60	20	0	68	2	45	43		2	11	69	23	0	38	0	18	52	44	14	15	38	3	1	3	7	13	0
			2	77	14	19	66	57	19	69	12	0	73	1	49	32		1	9	78	18	0	42	0	14	68	55	6	1	39	1	1	1	8	17	0
			X	11	100	0	0	73	45	55	0	0	82	0	45	45		0	0	82	36	0	73	0	9	73	55	9	0	64	0	0	0	9	0	0
	58	Development of high energy converting efficiency machines which apply the biological energy converting mechanism.	1	57	9	18	74	64	32	61	7	0	65	56	25	32		4	11	40	16	2	25	0	42	53	28	7	9	53	4	0	7	4	7	2
			2	46	7	17	76	60	21	79	0	0	76	52	24	13		0	11	52	7	0	22	0	41	61	26	0	0	59	2	0	7	9	13	0
			X	3	100	0	0	83	67	33	0	0	67	67	33	33		0	0	67	33	0	0	0	33	33	0	0	0	67	0	0	0	33	0	0
	59	Development of micromachine elements (integration of machine elements, sensors and electronic circuitry) capable of detecting and controlling physical processes and quantities such as motion, light, sound and heat.	1	89	18	18	64	66	40	44	15	1	82	15	61	13		0	3	62	33	0	64	2	19	49	44	28	3	51	3	0	2	11	7	1
			2	76	17	12	71	65	33	59	8	0	80	4	62	5		0	3	67	26	0	68	1	14	66	46	12	0	58	3	0	1	12	9	0
			X	13	100	0	0	85	75	17	8	0	77	15	46	8		0	0	62	54	0	69	8	8	54	46	0	0	62	0	0	8	15	8	0
	60	Development of new evolving structure systems and self-multiplicating and repairing devices via elucidation of biological mechanisms (e.g. homeostatics and homeodynamics including autosynthetic control and in vivo nuclear reaction (reaction by which elements are formed in a living organism)).	1	57	12	25	63	63	33	50	17	0	74	14	25	53		7	12	60	16	2	37	0	32	70	32	11	12	60	2	2	7	11	12	2
			2	47	6	23	70	62	26	70	4	0	83	9	19	45		2	15	68	11	0	30	0	28	79	28	4	2	64	2	0	9	17	17	0
			X	3	100	0	0	67	33	67	0	0	67	0	0	67		0	0	67	67	0	67	0	33	67	33	0	0	100	0	0	0	0	33	0

(Note) See page 7 for the interpretation of the graphs.

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Living organisms	61	Practical use of basic chemical product manufacturing processes that utilize the efficiency of microorganisms living in extreme environmental conditions (e.g. ultra high pressure and high pH).	1	21	0	10	90	51	16	58	26	0	43	62	5	24		0	14	38	19	5	24	0	43	38	24	10	24	48	5	0	14	5	10	0
			2	17	0	6	94	58	25	56	19	0	47	53	6	12		0	6	47	24	6	24	0	35	35	18	6	24	65	6	0	24	12	12	0
			X	0	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	62	Widespread use of biomimetics (technology to study and imitate superior functions and mechanisms of living organisms and synthetically create even better systems) throughout industries.	1	61	13	30	57	59	28	53	17	2	74	18	25	51		8	8	51	28	0	36	0	30	61	43	15	7	46	3	0	5	10	18	2
			2	45	9	29	62	59	25	61	14	0	76	11	22	36		7	9	49	16	0	40	0	29	60	40	9	2	49	4	0	4	13	20	0
			X	4	100	0	0	75	50	50	0	0	50	0	50	75		0	0	100	0	0	50	0	0	75	25	0	0	50	0	0	0	0	50	0
	63	Widespread use of biofabrication (technology to produce materials and living organisms that are useful for humans by incorporating living organisms or their building blocks into components for production processes) in various industries.	1	42	2	14	83	58	27	56	12	5	71	40	14	29		7	14	48	33	5	33	0	29	40	24	5	21	33	5	0	19	10	21	2
			2	28	4	14	82	61	26	67	7	0	82	36	14	25		4	25	54	29	0	36	0	29	54	25	4	14	43	4	0	11	7	21	0
			X	1	100	0	0	50	0	100	0	0	100	0	0	0		0	100	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0
	64	Development of techniques to consciously design machines (evolving machines) and manufacturing systems in which the rules of self-organization manufacturing (a manufacturing method that utilizes self-organizing machines and materials) are directly applied.	1	86	16	23	60	55	23	52	23	2	77	3	15	44		9	14	47	16	0	28	1	29	57	30	12	2	52	1	0	5	7	12	2
			2	70	14	23	63	55	17	67	16	0	83	0	13	43		9	14	56	13	0	29	0	31	71	29	10	0	63	1	0	4	14	20	0
			X	10	100	0	0	60	20	80	0	0	80	0	0	80		10	10	70	10	0	20	0	20	80	0	20	0	60	0	0	20	10	10	0
Human beings	65	Widespread use of robots for work in hazardous or extreme conditions, ensuring worker safety, while bringing about changes in employment opportunities and modes.	1	154	19	23	58	66	40	46	13	1	67	16	77	3		1	5	51	22	0	73	0	15	36	51	22	3	45	22	1	3	18	19	2
			2	127	16	24	60	65	37	52	10	2	74	10	76	1		0	4	52	11	0	79	0	13	34	60	13	0	56	17	0	2	21	20	0
			X	20	100	0	0	71	55	30	5	10	70	5	70	5		0	5	50	5	0	95	0	0	45	45	5	0	50	25	0	0	30	30	0
	66	Development of brain support systems that make judgment processes, skills, know-how and experiences of some people accessible to others for reuse or learning purposes.	1	112	12	26	63	60	28	60	12	1	68	1	51	35		4	8	62	24	2	37	0	21	52	39	18	10	43	4	1	3	17	29	1
			2	92	10	25	65	56	17	73	10	0	82	1	48	27		5	7	73	17	0	40	0	13	68	39	8	1	49	2	0	2	14	39	0
			X	9	100	0	0	67	33	67	0	0	78	0	67	33		11	0	78	11	0	67	0	0	67	44	11	0	44	11	0	0	33	67	0
	67	Widespread use of production systems that provide comprehensive support for senior citizens suffering from functional degeneration (cerebral and physical) and for people with disabilities.	1	116	8	23	69	69	45	45	8	3	46	3	91	6		3	4	38	39	1	35	1	27	44	40	14	4	53	16	2	0	23	28	2
			2	91	10	18	73	73	51	43	4	2	48	0	90	4		0	2	45	49	0	38	0	21	45	40	7	0	75	9	2	0	24	30	0
			X	9	100	0	0	78	67	22	0	11	78	0	100	33		0	0	67	33	0	33	0	11	56	22	0	0	89	11	0	0	22	33	0
	68	Practical use of "behavior alarm" systems based on elucidation of physical and psychological mechanisms that cause human error.	1	88	9	26	65	63	35	48	14	2	47	6	81	18		3	5	44	22	1	30	1	33	53	45	13	2	44	8	0	1	27	31	2
			2	78	6	22	72	62	29	64	6	1	47	3	78	8		1	5	50	15	0	32	0	33	63	49	6	0	53	4	0	1	27	35	0
			X	5	100	0	0	65	40	40	20	0	60	0	100	0		0	0	60	40	0	60	0	0	60	20	20	0	100	0	0	0	40	40	0
	69	Widespread use of safety measures for industrial complexes, aircraft, tankers, large storage tanks, as suitable for their size and functionality, based on potential danger assessment and accident scenario prediction techniques.	1	96	11	20	69	71	47	42	11	0	64	30	59	5		0	4	59	34	1	31	0	30	38	51	11	5	44	24	0	6	24	5	2
			2	81	6	17	77	73	50	43	8	0	78	25	59	2		0	4	64	32	0	31	0	28	33	64	7	2	58	20	0	5	31	1	0
			X	5	100	0	0	90	80	20	0	0	80	40	60	20		0	0	100	60	0	40	0	0	0	60	0	0	60	20	0	20	20	0	0
	70	Widespread use of earthquake damage alleviation systems for industrial complexes, nuclear facilities, etc. based on the early operation of safety devices in response to initial mild tremors.	1	94	7	22	70	84	70	28	1	1	40	48	61	4		1	4	40	16	1	70	0	16	33	41	17	5	61	21	0	9	18	5	2
			2	80	3	20	78	88	78	19	3	1	41	49	66	1		1	3	38	10	0	78	0	8	35	49	8	3	75	11	0	4	16	3	0
			X	2	100	0	0	100	100	0	0	0	50	100	50	0		0	0	100	0	0	100	0	0	50	100	0	0	50	50	0	0	0	0	0

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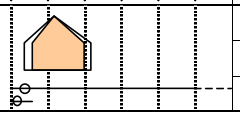
Human beings	71	Spread of science museums capable of fostering scientific skills of children through play based on the applied use of natural history and science education techniques.	1	113	4	13	83	60	34	41	23	3	42	8	38	54		0	4	64	35	0	20	0	20	19	22	24	3	44	13	4	1	3	24	1
			2	95	4	13	83	60	34	42	22	2	44	6	48	58		0	1	78	33	0	20	0	13	16	20	25	0	59	12	2	0	1	29	0
			X	4	100	0	0	88	75	25	0	0	0	0	50	100		0	0	100	75	0	25	0	0	25	50	50	0	50	25	0	0	0	25	0

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