ICV TA&K
Technology Advisory
& Knowledgebase

Global Future Industry Index 2024

PREFACE

The Global Future Industry Index is a research initiative crafted by ICV TA&K, bolstered by support from esteemed organizations such as WIPO, OECD, and IRENA. This study, underpinned by rigorous secondary research, data collation from diverse institutions, and interviews with domain experts in biotechnology, green energy, and advanced information technologies, seeks to comprehensively assess the capabilities of over 20 countries and regions across future industry layout, development, innovation investment, and environmental sustainability.

Future industries, in this context, are defined as forward-looking and strategically significant sectors involving technology, innovation, and societal advancement. These industries encompass emerging technologies, inventive business models, and sectors with profound impacts on society, the economy, and the environment. Our research focuses on key domains such as artificial intelligence, biotechnology, green energy, humanoid robotics, high-performance computing, quantum information, neuroscience and neuromorphic intelligence, and advanced communications. The development of these fields significantly shapes industrial structures, employment dynamics, and global competitiveness.

Through the deployment of this index, our objective is to furnish invaluable insights to global decision-makers, business leaders, and investors concerning the performance and developmental trajectories of nations in the realm of future industries. We express our gratitude for the adept composition by the ICV TA&K team and acknowledge the pivotal role played by all experts involved in this research, contributing their time, insights, and specialized knowledge to the formulation of this index.

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Executive summary

The future industry emerges as a result of significant technological innovations. Compared to strategic emerging industries, it more precisely reflects the new direction of technological and industrial progress in the future, playing a crucial, supportive, and leading role in economic and social transformations. In recent years, the future industry has become a new competitive frontier for major nations around the world, with countries actively planning their paths for future industrial development.

1

2024 GFII Ranking Update:
The United States and China have ranked in the top two for three consecutive years, while the rankings of several other countries have fluctuated.

Compared to the 2023 rankings, the overall rankings of the United States and China remain unchanged, staying in the top two. The rankings of Germany, Switzerland, Sweden, France, and Canada have all increased, while South Korea, the Netherlands, Japan, Singapore, Denmark, and Italy have seen declines. Among them, the United States maintains a leading position in multiple fields, China ranks first in Talent and Education, Switzerland ranks first in International Collaboration and Adaptability to Trends, and Sweden ranks first in Sustainability and Environment.

2

2024 City Comprehensive Ranking:
Cities that lead the global trends in technological innovation and stand out in the diverse competitive landscape.

San Francisco-San Jose retains the top overall ranking, excelling in AI, Clean Energy, Neuroscience, and Biotechnology, though it lags in Deep Space, Low-Altitude and Deep Sea, and Embodied Intelligence. Other strong cities include London-Oxford-Cambridge, which shows balanced growth and notable achievements in Quantum Information, AI, and Neuroscience, and Beijing, which leads in Advanced Connectivity. New York also stands out in Quantum Information, Deep Space, and Biotechnology. The United States and China each have five cities on the list, while Germany has two, demonstrating significant competition.

3

2024 Technology Twin Stars Shine:
The deepening of generative AI and multimodal models, practical breakthroughs in quantum computing.

Generative AI technology continues to deepen, with the release of next-generation language models like GPT-4o enhancing AI's generative capabilities, particularly making significant progress in multimodal applications such as text, images, and video.

01
Executive summary

The application fields of quantum computing are continuously expanding, especially with the deepening of innovative cooperation in "quantum computing + finance," and it will play a crucial role in fields such as artificial intelligence and drug development.

New Technology Trends in 2024: Interdisciplinary integration is accelerating.

The interdisciplinary integration of AI with fields like robotics and cognitive science is expanding humanoid robots' applications, promoting more flexible and intelligent operations. In clean energy, the fusion of fourth-generation nuclear technology with materials science and quantum physics shapes the future of nuclear energy, while hydrogen energy's commercialization, accelerated by chemical engineering and environmental science, drives energy transformation. In neuroscience and neuromorphic intelligence, the integration of BCI technology with computational neuroscience and electronic engineering fuels market growth, enhancing the precision of brain analysis. This fusion is fueling innovation and progress across these fields.

02

Introduction:Tech Evolution, Global Impact

02
Introduction: Tech Evolution, Global Impact

How do we define the future industry of 2024?

Based on the technological hotspots in 2024 and comprehensively considering various factors such as industrial technological innovation and trends, industrial diversity and the development of emerging industries, sustainability and environmental protection, talent and education, and international cooperation, this report has selected eight future industries. The selected industries include quantum technology, deep space, low-altitude and deep sea, AI, clean energy, embodied intelligence, neuroscience and neuromorphic intelligence, advanced connectivity, and biotechnology.

These future industries can be divided into two categories. One category consists of advanced industries that already exist and will remain an integral part of various industrial economies in the long term, such as deep space, low-altitude and deep sea, AI, clean energy, embodied intelligence, advanced connectivity. The other category includes fields that are expected to develop into advanced industries within the next 10 to 15 years, including quantum technology, neuroscience and neuromorphic intelligence, and biotechnology.

Compared with the future industries released in 2023, this report has added the low - altitude economy industry to its industrial layout. This is mainly because in 2024, the low - altitude economy was incorporated into the national strategy, with continuous increases in industrial investment and policy support, which have promoted the rapid development of the low - altitude economy.

Meanwhile, the report has adjusted the controllable nuclear fusion industry to the broader concept of clean energy, thus expanding the scope of industrial coverage. Behind this adjustment lies a precise insight into the energy development trend and a profound consideration of industrial diversification. In addition to controllable nuclear fusion, other clean energy sources such as hydrogen energy and energy storage also achieved remarkable results in 2024. This adjustment can more comprehensively reflect the current development status and future trends of the energy industry, highlighting the importance of the diversified development of clean energy.

02
Introduction: Tech Evolution, Global Impact

Methodology: The Global Future Industry Index in 2024

The Global Future Industry Index is the third annual comparative ranking that provides dynamic updates and tracking of various sectors within the future industries each year. It comprehensively compares the layout and development of future industries, innovation investments, and environmental sustainability capabilities among over 20 countries and regions globally, collectively representing approximately 75% of the global GDP.

The index was developed through in-depth primary and secondary research processes. Secondary research involves continuous review of several hundred articles, research reports released by NGOs such as UNIDO & WIPO, government policy documents, and ongoing examination of scientific literature. Primary research includes nearly 30 in-depth interviews with experts from various fields globally, including quantum scientists, biological scientists, and professionals in various scientific and research domains, technology experts, government policymakers, non-governmental organization activists, as well as technology entrepreneurs and venture capitalists in various sectors of the future industries.

This research process informed an evaluation and selection of distinct sets of country-level data to become the indicators of the Future Industry Index; the 2024 edition now comprises 15 such indicators. The indicator datasets were turned into ranked scores in one of two ways.

For quantitative metrics, such as growth rates or values, each data point for each country was scaled up or down using minimum-maximum normalization to develop a range of scores across all countries for that indicator. For data that was largely qualitative or nonstandard, a ranking categorization system was developed, and each country was assigned a score.

Once all 15 indicators were scored, they were organized into separate pillars.The data came from a wide range of latest publicly available sources. These include the International Monetary Fund (IMF), the International Renewable Energy Agency (IRENA), the Organization for Economic Co-operation and Development (OECD), the World Bank, the United Nations Food and Agriculture Association (FAO), the World Intellectual Property Organization (WIPO), and the National Institute of Standards and Technology (NIST),The International Federation of Robotics (IFR) etc. In some cases, ICV TA&K researchers expanded and refined existing datasets, conducting additional cross-comparative country-level research to fill in data gaps, or to create rankings out of nonstandard data.

This was done specifically for several indicators in the future industry policy pillar, including the Policy Pivot, and in a new indicator added to this year's index.

As in past editions, the structure of the Global Future Industry Index 2024 is made up of five pillars:

Pillar 1

Innovation Ecosystem and Technological Capability -
This pillar measures the overall environment and proficiency of a region or entity in fostering innovation within its ecosystem and its technological capabilities.

The indicators within this pillar include the following:

• R&D and Technology Investment: Evaluate the level of investment in research and technological innovation by countries or cities, including both government and corporate R&D expenditures.

• Attraction and Cultivation of Tech Talent: Examine the ability to attract and cultivate high-level tech talent, including talent strategies employed by research institutions and businesses.

• Start-up Activity: Measure the number of start-ups, investment activities, and the presence and development of incubators, reflecting the vibrancy of the innovation ecosystem.

• Development of Innovation Ecosystem: Assess the construction and operation of technology parks, research centers, and technology innovation incubators to support innovative development.

• Construction of Digital Infrastructure: Evaluate investments in digital technologies such as 5G and the Internet of Things (IoT) by cities or countries to support the digital economy and technological applications.

Pillar 2

Industry Diversity and Emerging Industries-
This pillar assesses the diversity of industries within a region or entity and its readiness to embrace emerging sectors.

The indicators within this pillar include the following:

· Potential for Development in Emerging Industries: Assess the potential and innovation capabilities of future industries, including areas such as artificial intelligence, biotechnology, and new energy.

· Capability in Building Industrial Ecosystems: Evaluate the ability and level of countries or city clusters in building ecosystems for future industries.

· Industry Diversity: Evaluate the diversity of industrial structures in cities or countries, avoiding excessive reliance on a specific industry.

Pillar 3

Sustainability and Environment –
This pillar measures the commitment and efforts of a region or entity in promoting sustainability and environmental conservation.

The indicators measure the following:

· Utilization of Renewable Energy: Examine progress in the utilization of renewable energy (solar, wind, etc.) by cities or countries.

· Environmental Policies and Ecological Protection: Evaluate government-issued environmental policies and ecological protection measures to ensure sustainable development.

Pillar 4

Talent and Education –
This pillar measures the quality of human resources and educational initiatives within a region or entity.

The indicators measure the following:

· Cultivation of High-Tech Talent: Evaluate the quality and quantity of higher education institutions and tech training to ensure an adequate supply of high-quality talent.

· Innovative Education and Vocational Training: Examine innovative education and vocational training programs that match industry needs, enhancing the innovation and practical application skills of talents.

Pillar 5

International Collaboration and Adaptability to Trends-
This pillar measures the extent to which a region or entity engages in global collaboration and adapts to emerging trends.

The indicators measure the following:

· International Innovation Collaboration: Measure the level of innovation collaboration with other countries or cities, including research collaboration and technology exchange.

· Participation in International Industry Chains: Evaluate the degree of participation in international industry chains and global value chains to expand markets and strengthen international competitiveness.

· Adaptability to Future Industry Policies and Trends: Examine whether relevant policies contribute to adapting to future industry trends.

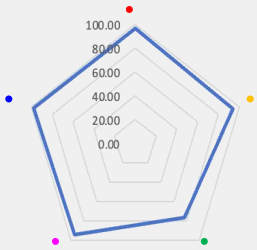
03

Global Future Industries Assessment 2024:

National Perspectives Ranking

Country	Overall						Innovation Ecosystem and Technological Capability		Industry Diversity and Emerging Industries		Sustainability and Environment		Talent and Education		International Collaboration and Adaptability to Trends	
	2024		2023		2022	score	Rank	score	Rank	score	Rank	score	Rank	score	Rank	score
United States	1	—	1	—	1	93.01	1	96.62	1	94.30	13	76.86	2	94.66	1	97.69
China	2	—	2	—	2	90.76	2	91.10	3	91.81	10	81.49	4	91.10	2	95.91
United Kingdom	3	—	3	↑	5	90.10	3	88.52	2	93.41	8	86.12	6	89.32	4	92.52
Germany	4	↑	5	↑	6	87.06	6	86.83	5	85.58	5	89.32	11	80.06	3	94.13
Switzerland	5	↑	6	↓	3	85.45	8	85.32	10	80.06	4	89.68	1	98.22	14	75.08
Sweden	6	↑	7			85.19	5	87.10	4	87.90	2	96.08	8	86.47	18	70.63
France	7	↑	9	—	9	82.90	10	79.17	8	84.69	7	86.47	12	78.64	5	87.36
Canada	8	↑	10			81.66	13	76.68	7	85.23	18	71.16	7	87.90	6	85.94
Australia	9	↑	15			81.51	9	80.06	14	77.04	14	75.44	3	91.28	8	82.56
South Korea	10	↓	4	↑	8	81.48	4	87.45	6	85.40	19	70.81	13	78.46	12	81.13
Netherlands	11	↓	8	↑	10	81.23	12	77.66	13	77.39	3	92.52	9	84.51	13	77.75
Japan	12	↓	11	↓	4	80.66	7	86.65	9	83.45	16	71.88	15	75.44	10	82.20
Singapore	13	↓	12	↓	7	78.68	11	79.00	18	74.37	15	74.72	5	90.57	15	73.66
Denmark	14	↓	13			77.87	16	74.55	17	76.15	1	97.15	14	78.28	19	68.85
Spain	15	↑	16			76.83	17	73.48	11	79.00	9	84.69	18	67.78	11	82.02
Israel	16	↑	17			76.02	14	75.70	19	72.23	12	78.64	10	81.49	17	72.77
India	17	↑	18			75.77	14	75.70	15	76.50	11	79.35	20	64.93	7	83.27
Italy	18	↓	14			74.74	18	71.52	12	77.75	17	71.88	16	70.45	9	82.20
Portugal	19	—	19			73.48	20	70.10	16	76.33	6	87.90	17	69.74	20	67.78
Russia	20	—	20			69.16	19	70.90	20	68.14	20	65.11	19	66.89	16	73.30

NO.1 United States



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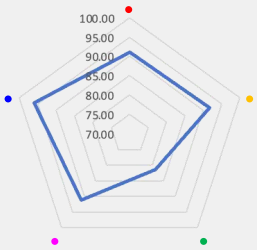

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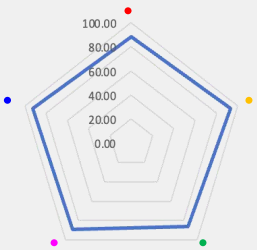

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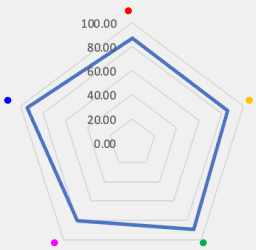

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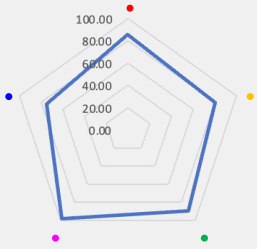

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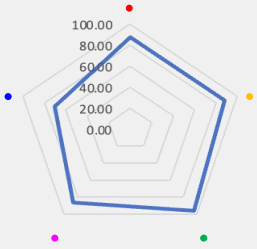

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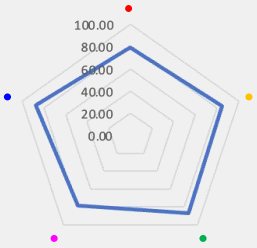

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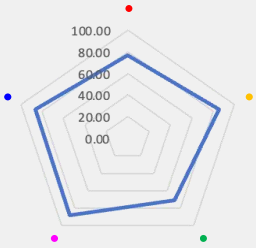

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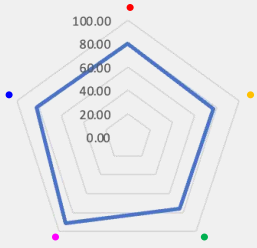

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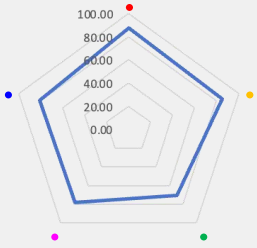

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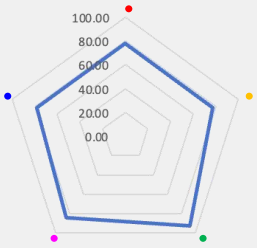

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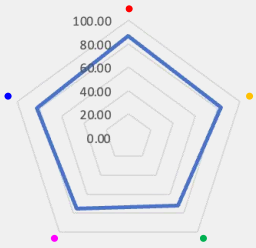

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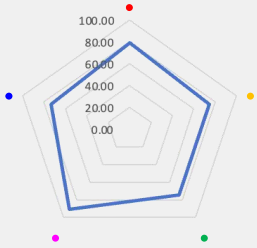

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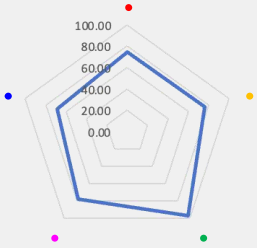

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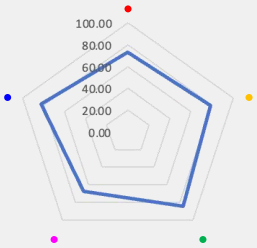

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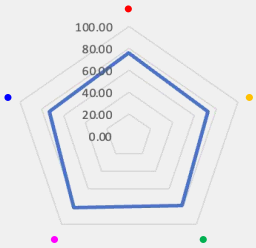

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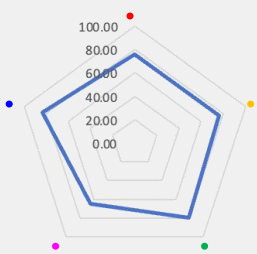

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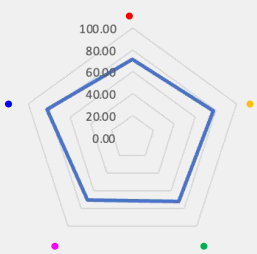

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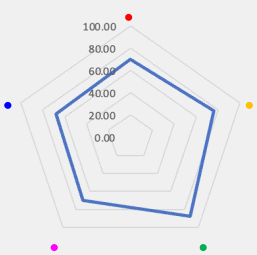

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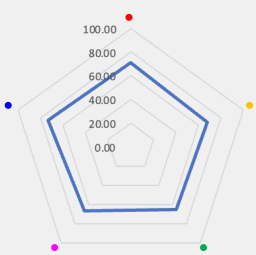


- Innovation Ecosystem and Technologzical Capability
- Industry Diversity and Emerging Industries
- Sustainability and Environment
- Talent and Education
- International Collaboration and Adaptability to Trends

The Global Future Industry Institute (GFII) has identified 20 countries that stand out in terms of technological innovation strength and future industrial development potential. The institute evaluates candidate countries across five dimensions: Innovation Ecosystem and Technological Capability, Industry Diversity and Emerging Industries, Sustainability and Environment, Talent and Education, International Collaboration and Adaptability to Trends.

The United States and China have ranked first and second respectively in the GFII's evaluation for three consecutive years. Among them, the United States remains an unparalleled leader in the field of future industries, topping the list in aspects such as Innovation Ecosystem and Technological Capability, industry Diversity and Emerging Industries, International Collaboration and Adaptability to Trends. China has shown excellent performance in dimensions such as Innovation Ecosystem and Technological Capability, and International Collaboration and Adaptability to Trends.

Compared with 2023, Germany (5th), Switzerland (6th), Sweden (7th), France (9th), Canada (10th), Australia (15th), Spain (16th), Israel (17th) and India (18th) all moved up in the rankings in 2024. On the other hand, South Korea, the Netherlands, Japan, Singapore, Denmark and Italy all dropped in the rankings in 2024, ranking 10th, 11th, 12th, 13th, 14th and 18th respectively. Among them, Switzerland ranked first in talent and education, and Denmark led in sustainability and environment (ranked 1st).

03
Global Future Industries Assessment 2024: National Perspectives Ranking

Innovation Ecosystem and Technological Capability

Country	Innovation Ecosystem and Technological Capability		1.1 R&D and Technology Investment		1.2 Attraction and Cultivation of Tech Talent		1.3 Start-up Activity		1.4 Development of Innovation Ecosystem		1.5 Construction of Digital Infrastructure	
	Rank/20	*score/100*	*Rank/20*	*score/100*	*Rank/20*	*score/100*	*Rank/20*	*score/100*	*Rank/20*	*score/100*	*Rank/20*	*score/100*
United States	1	96.62	3	94.66	1	98.22	1	98.22	3	94.66	1	98.22
China	2	91.10	10	82.20	2	96.44	2	96.44	6	87.54	3	94.66
United Kingdom	3	88.52	8	85.76	6	89.32	5	91.10	4	91.10	9	83.98
South Korea	4	87.45	2	96.44	5	91.10	13	76.86	5	89.32	13	76.86
Sweden	5	87.10	4	92.88	16	71.52	9	83.98	2	96.44	4	92.88
Germany	6	86.83	7	87.54	3	94.66	10	82.20	8	83.98	10	82.20
Japan	7	86.65	4	92.88	4	92.88	4	92.88	10	78.64	14	75.08
Switzerland	8	85.32	6	89.32	17	69.74	11	80.42	1	98.22	6	89.32
Italy	9	71.52	18	67.96	12	78.64	19	66.18	13	71.52	17	69.74
Australia	9	80.06	16	71.52	8	85.76	7	87.54	12	73.30	8	85.76
France	10	79.17	12	78.64	10	82.20	16	71.52	9	80.42	11	80.42
Singapore	11	79.00	13	76.86	15	73.30	6	89.32	14	69.74	2	96.44
Netherlands	12	77.66	11	80.42	19	66.18	17	69.74	7	85.76	7	87.54
Canada	13	76.68	14	75.08	9	83.98	20	64.40	11	76.86	12	78.64
Israel	14	75.70	1	98.22	13	76.86	18	67.96	16	67.96	20	64.40
India	14	75.70	20	64.40	7	87.54	3	94.66	17	66.18	18	67.96
Denmark	16	74.55	9	83.98	18	67.96	15	73.30	19	64.40	5	91.10
Spain	17	73.48	17	69.74	11	80.42	14	75.08	14	69.74	16	71.52
Russia	19	70.90	19	66.18	14	75.08	8	85.76	19	64.40	19	66.18
Portugal	20	70.10	15	73.30	20	64.40	12	78.64	17	66.18	15	73.30

Innovation Ecosystem and Technological Capability are key indicators of a country's global competitiveness, encompassing R&D investment, tech talent development, start-up activities, innovation ecosystems, and digital infrastructure. The United States and China lead the rankings in this area. Among them, the United States ranks first in the Attraction and Cultivation of Tech Talent, Start-up Activity, and Construction of Digital Infrastructure. China ranks second in the Attraction and Cultivation of Tech Talent and Start-up Activity. In terms of the future industry index, Israel performs best in R & D and Technology Investment. Switzerland ranks first in the Development of Innovation Ecosystem, and Singapore has also achieved good results in the Construction of Digital Infrastructure.

03
Global Future Industries Assessment 2024: National Perspectives Ranking

Industry Diversity and Emerging Industries

Country	Industry Diversity and Emerging Industries		2.1 Potential for Development in Emerging Industries		2.2 Capability in Building Industrial Ecosystems		2.3 Industry Diversity	
	Rank/20	*score/100*	*Rank/20*	*score/100*	*Rank/20*	*score/100*	*Rank/20*	*score/100*
United States	1	94.30	2	96.44	3	94.66	5	91.10
United Kingdom	2	93.41	4	92.88	5	91.10	2	96.44
China	3	91.81	1	98.22	10	82.20	4	92.88
Sweden	4	87.90	11	80.42	2	96.44	6	89.32
Germany	5	85.58	6	89.32	8	85.76	11	80.42
South Korea	6	85.40	7	87.54	6	89.32	12	78.64
Canada	7	85.23	5	91.10	13	76.86	8	85.76
France	8	84.69	8	85.76	11	80.42	7	87.54
Japan	9	83.45	3	94.66	12	78.64	15	73.30
Switzerland	10	80.06	13	76.86	1	98.22	19	66.18
Spain	11	79.00	10	82.20	17	69.74	9	83.98
Italy	12	77.75	17	69.74	16	71.52	3	94.66
Netherlands	13	77.39	16	71.52	7	87.54	14	75.08
Australia	14	77.04	9	83.98	15	73.30	16	71.52
India	15	76.50	12	78.64	19	66.18	9	83.98
Portugal	16	76.33	19	66.18	18	67.96	1	98.22
Denmark	17	76.15	14	75.08	9	83.98	17	69.74
Singapore	18	74.37	18	67.96	4	92.88	20	64.40
Israel	19	72.23	15	73.30	14	75.08	18	67.96
Russia	20	68.14	20	64.40	20	64.40	13	76.86

Industry diversity and emerging industries are crucial for a country's economic resilience, which helps control costs and achieve stable development. This encompasses the development potential of emerging industries, the ability to build industrial ecosystems, and industry diversity.

Judging from the ranking results of industry diversity and emerging industries, the United States has high development potential in emerging industries such as quantum technology and biotechnology.

China also performed well in the fields of artificial intelligence and new energy, ranking third. There are significant gaps in the performance of other countries in this regard.

03
Global Future Industries Assessment 2024: National Perspectives Ranking

Sustainability and Environment

	Sustainability and Environment		3.1 Utilization of Renewable Energy		3.2 Environmental Policies and Ecological Protection	
Country	*Rank/20*	*score/100*	*Rank/20*	*score/100*	*Rank/20*	*score/100*
Denmark	1	97.15	2	96.44	1	98.22
Sweden	2	96.08	1	98.22	4	92.88
Netherlands	3	92.52	5	91.10	3	94.66
Switzerland	4	89.68	3	94.66	10	82.20
Germany	5	89.32	6	89.32	6	89.32
Portugal	6	87.90	8	85.76	5	91.10
France	7	86.47	4	92.88	13	76.86
United Kingdom	8	86.12	7	87.54	9	83.98
Spain	9	84.69	9	83.98	8	85.76
China	10	81.49	10	82.20	11	80.42
India	11	79.35	18	67.96	2	96.44
Israel	12	78.64	12	78.64	12	78.64
United States	13	76.86	11	80.42	16	71.52
Australia	14	75.44	13	76.86	15	73.30
Singapore	15	74.72	19	66.18	7	87.54
Japan	16	71.88	15	73.30	17	69.74
Italy	17	71.88	17	69.74	14	75.08
Canada	18	71.16	15	73.30	18	67.96
South Korea	19	70.81	14	75.08	20	64.40
Russia	20	65.11	20	64.40	19	66.18

This dimension assesses the efforts made by countries in sustainable development and environmental protection, with a focus on the adoption of renewable energy, environmental policies, and ecological conservation.

Denmark and Sweden have shown strong performance in Sustainability and Environment. Denmark is a global leader in the wind energy sector, boasting a large number of wind power facilities and advanced wind energy technologies. Denmark regards energy efficiency as the primary energy source and has achieved remarkable results in reducing energy consumption through energy - efficiency improvements. Sweden has made significant progress in energy transition. The electricity and construction industries have basically achieved decarbonization, and it also leads the way in the decarbonization of heavy industries.

03
Global Future Industries Assessment 2024: National Perspectives Ranking

Talent and Education

	Talent and Education		4.1 Cultivation of High-Tech Talent		4.2 Innovative Education and Vocational Training	
Country	*Rank/20*	*score/100*	*Rank/20*	*score/100*	*Rank/20*	*score/100*
Switzerland	1	98.22	1	98.22	1	98.22
United States	2	94.66	3	94.66	3	94.66
Australia	3	91.28	4	92.88	7	87.54
China	4	91.10	5	91.10	5	91.10
Singapore	5	90.57	2	96.44	13	76.86
United Kingdom	6	89.32	6	89.32	6	89.32
Canada	7	87.90	8	85.76	4	92.88
Sweden	8	86.47	7	87.54	9	83.98
Netherlands	9	84.51	9	83.98	8	85.76
Israel	10	81.49	14	75.08	2	96.44
Germany	11	80.06	10	82.20	14	75.08
France	12	78.64	12	78.64	12	78.64
South Korea	13	78.46	13	76.86	10	82.20
Denmark	14	78.28	11	80.42	15	73.30
Japan	15	75.44	15	73.30	11	80.42
Italy	16	70.45	16	71.52	18	67.96
Portugal	17	69.74	17	69.74	17	69.74
Spain	18	67.78	19	66.18	16	71.52
Russia	19	66.89	18	67.96	20	64.40
India	20	64.93	20	64.40	19	66.18

This part mainly focuses on evaluating the talent and education levels of different countries, covering aspects such as the cultivation of high-tech talents, innovative education, and vocational training.

Switzerland and the United States have achieved remarkable results in talent and education indicators. Part of the reason is that they both have outstanding performances in talent competitiveness, QS university rankings, and industry-university-research cooperation. In addition, Singapore also got a high score in the ranking of the Cultivation of High-Tech Talent and ranked second. Israel also performed excellently in Innovative Education and Vocational Training.

03
Global Future Industries Assessment 2024: National Perspectives Ranking

International Collaboration and Adaptability to Trends

	International Collaboration and Adaptability to Trends		5.1 International Innovation Collaboration		5.2 Participation in International Industry Chains		5.3 Adaptability to Future Industry Policies and Trends	
Country	*Rank/20*	*score/100*	*Rank/20*	*score/100*	*Rank/20*	*score/100*	*Rank/20*	*score/100*
United States	1	97.69	1	98.22	2	96.44	1	98.22
China	2	95.91	2	96.44	1	98.22	5	91.10
Germany	3	94.13	4	92.88	3	94.66	2	96.44
United Kingdom	4	92.52	3	94.66	7	87.54	3	94.66
France	5	87.36	7	87.54	6	89.32	9	83.98
Canada	6	85.94	5	91.10	10	82.20	12	78.64
India	7	83.27	9	83.98	11	80.42	8	85.76
Australia	8	82.56	6	89.32	16	71.52	10	82.20
Italy	9	82.20	8	85.76	8	85.76	18	67.96
Japan	10	82.20	11	80.42	5	91.10	15	73.30
Spain	11	82.02	10	82.20	13	76.86	6	89.32
South Korea	12	81.13	12	78.64	8	85.76	11	80.42
Netherlands	13	77.75	15	73.30	4	92.88	19	66.18
Switzerland	14	75.08	14	75.08	14	75.08	14	75.08
Singapore	15	73.66	16	71.52	12	78.64	16	71.52
Russia	16	73.30	13	76.86	15	73.30	20	64.40
Israel	17	72.77	17	69.74	20	64.40	4	92.88
Sweden	18	70.63	20	64.40	17	69.74	7	87.54
Denmark	19	68.85	19	66.18	18	67.96	13	76.86
Portugal	20	67.78	18	67.96	19	66.18	17	69.74

This part is dedicated to evaluating the capabilities of different countries in conducting international cooperation and adapting to global trends. The evaluation dimensions include international innovation cooperation, participation in international industrial chains, and adaptability to future industrial policies and trends. The United States, China, and Germany have shown excellent performance in International Collaboration and Adaptability to Trends. The United States ranks first in International Innovation Collaboration and Adaptability to Future Industry Policies and Trends. China ranks first in Participation in International Industry Chains, and Germany also performs well in these aspects. Other countries such as the United Kingdom and France have also secured good rankings in this part.

04

Global Future Industries Assessment 2024:

Urban Perspectives Ranking

04
Global Future Industries Assessment 2024: Urban Perspectives Ranking

2024		2023	City/MAs	Score
1	—	1	San Francisco-San Jose	98.30
2	—	2	London-Oxford-Cambridge	96.60
3	—	3	Beijing	94.90
3	↑	6	New York	93.20
5	—	5	Boston	91.50
6	↑	14	Paris	89.80
7	↑	17	Shanghai	88.10
8	↓	6	Tokyo-Yokohama	86.40
9	↓	8	Los Angeles	84.70
10	↑	19	Washington DC-Baltimore	83.00
11			Hangzhou	81.30
12	↓	4	Munich-Stuttgart	79.60
13			Singapore	77.90
14	↓	12	Hefei	76.20
15	↓	13	Berlin	74.50
16	↓	11	Seoul	72.80
17	↓	9	Guangdong-Hong Kong-Macao Greater Bay Area	71.10
18			Sydney	69.40
19	↑	20	Moscow	67.70
20	↓	17	Toronto	66.00

Note: refer to "Comprehensive analysis and ranking of future industries" for a detailed ranking of each industry segment

The city's future prospects ranking takes into account factors such as Quantum Technology, Deep Space, Low-altitude and Deep Sea, AI, Clean Energy, Embodied Intelligence, Neuroscience and Neuromorphic Intelligence, Advanced Connectivity, and Biotechnology, objectively reflecting the city's/metropolitan area's overall strength in these future industries.

San Francisco-San Jose, like in 2023, has earned the highest overall ranking. San Francisco is home to top research institutions and a large pool of innovative tech talent, leading the world in fields such as AI, Clean Energy, Neuroscience and Neuromorphic Intelligence, and Biotechnology. However, San Francisco is relatively weaker in the fields of Deep Space, Low-Altitude and Deep Sea, and Embodied Intelligence, ranking lower in these areas.

Besides the aforementioned cities, there are other cities with strong technological innovation capabilities, such as London-Oxford-Cambridge, Beijing, and New York. Among these, London-Oxford-Cambridge ranks second and has a relatively balanced development across various related fields, with notable achievements in Quantum Technology, Artificial Intelligence (AI), and Neuroscience and Neuromorphic Intelligence. Beijing, with its advanced technological environment, has attracted many emerging industry companies, particularly excelling in fields like Advanced Connectivity. New York has not only made significant strides in Quantum Information but also has outstanding performances in areas such as Deep Space and Deep Sea, as well as Biotechnology.

In this ranking, the United States and China have the most cities listed, with five cities each. Germany also has two cities on the list, which gives it a certain competitive advantage.

05

Comprehensive analysis and ranking of future industries

05
Comprehensive analysis and ranking of future industries

Quantum Technology

Definition

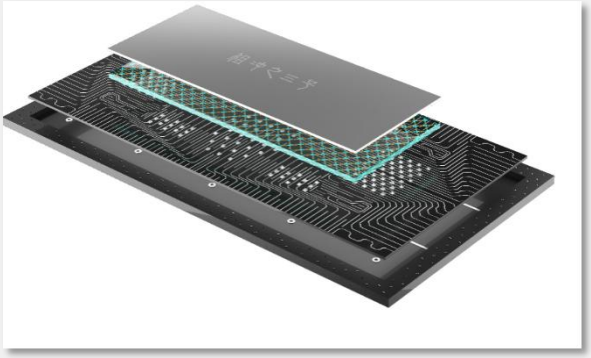
Quantum technology is a new field based on quantum mechanics, utilizing quantum effects like superposition, entanglement, and tunneling for information processing and transmission. Its key applications include quantum computing, quantum communication, quantum encryption, and quantum sensing. Quantum computing solves problems at unprecedented speeds, while quantum communication offers unbreakable security. Quantum encryption ensures data security through quantum principles, unlike traditional methods relying on complex mathematical problems. Quantum sensing enables highly precise measurements using quantum states. This technology is set to revolutionize industries such as aerospace, defense, automotive, chemicals, finance, and pharmaceuticals.

Summary of Outstanding Achievements in 2024

(1)The University of Science and Technology of China and others have developed the superconducting quantum processor 'Zuchongzhi 3' with 105 quantum bits

On December 16, 2024, a research team consisting of the University of Science and Technology of China, the Hefei National Laboratory for Microscale Material Science, and other institutions released the results of China's self-developed superconducting quantum computer, "Zuchongzhi 3."

The prototype of the "Zuchongzhi 3" superconducting quantum computer consists of 105 quantum bits and boasts high operational fidelity, with single-qubit gate fidelity, two-qubit gate fidelity, and readout fidelity reaching 99.90%, 99.62%, and 99.18%, respectively. The research team conducted a random circuit sampling experiment with 83 quantum bits and 32 cycles, successfully demonstrating exceptional performance on Zuchongzhi 3. In just a few hundred seconds, the system gathered one million samples. It is estimated that this task would be infeasible on the most powerful classical supercomputer, Frontier, which would require approximately 6.4×10^9 years to complete the same task. This leap in processing power makes the classical simulation cost six orders of magnitude higher than the Google SYC-67 and SYC-70 experiments, firmly establishing a new benchmark for quantum computing advantage. This work advances the frontier of quantum computing and lays the foundation for the era where quantum processors play a crucial role in addressing complex real-world challenges.



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Comprehensive analysis and ranking of future industries

Quantum Technology

Summary of Outstanding Achievements in 2024

(2) Breaking the quantum error correction threshold, Google has released its most powerful quantum chip, Willow

On December 10, 2024, Google unveiled its latest quantum chip, Willow. Willow features 105 quantum bits and demonstrates cutting-edge performance across multiple metrics, achieving two major milestones: First, as researchers expand the number of quantum bits, Willow is able to exponentially reduce errors, addressing a key challenge in quantum error correction that has been pursued for nearly 30 years — breaking the quantum error correction threshold. Second, Willow completed a standard benchmark calculation in five minutes, a task that would take one of today's fastest supercomputers, Frontier, approximately 10^25 years to complete.

(3) Quantinuum's ion trap quantum computer has become the first commercial quantum computer to achieve a 99.914(3)% two-qubit gate fidelity

On April 16, 2024, Quantinuum announced that its ion trap quantum computer became the first commercial quantum computer to achieve a 99.914(3)% two-qubit gate fidelity, reaching the critical "three nines" threshold. The quantum volume (QV) of Quantinuum's ion trap quantum computer has surpassed one million and is growing exponentially.

(4) The U.S.-based QCI has released the commercial version of the "Dirac-3" entropy quantum computer

On February 29, 2024, leading quantum computing company Quantum Computing Inc. (QCI) officially launched its innovative quantum optimization platform, the Dirac-3 Entropy Quantum Computer (EQC). With its unique nano-photonic design, the Dirac-3 EQC is capable of efficiently solving complex problems involving a large number of variables. A notable feature of the Dirac system is its use of so-called "quantum dits" (qdits), where each qdit can represent 200 distinct discrete states, a first in quantum computing devices that traditionally rely on quantum bits.

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Comprehensive analysis and ranking of future industries

Quantum Technology

Future development trends

Quantum technology is currently in a rapid development phase, with the progress toward commercialization and industrialization continuing to accelerate.

First, as quantum computing technology continues to mature and the demand for practical applications becomes increasingly clear, the scale of the quantum computing industry will continue to rise rapidly, taking up a significant portion of the overall quantum technology industry. In terms of technological development paths, multiple quantum computing approaches, including superconducting, ion trap, photonic, and semiconductor-based systems, will continue to evolve. Practical quantum error correction will become one of the key research and development areas, helping to improve the stability and accuracy of quantum computers. Meanwhile, the application fields of quantum computing will keep expanding, particularly in the innovation cooperation of "quantum computing + finance," which will continue to deepen and play an important role in areas such as artificial intelligence and drug development. Additionally, the participants in quantum computing will show increasing diversification. Beyond large tech companies and startups, telecom operators and traditional semiconductor manufacturers, among others, will enter the field, driving the rapid development and widespread application of quantum computing technology.

Secondly, in the field of quantum communication technology, the pace of technological innovation in the quantum communication industry will continue to accelerate. Currently, Quantum Key Distribution (QKD) is the most mature and widely used quantum communication technology, and significant breakthroughs have also been made in subfields such as quantum teleportation and quantum secure direct communication. In the future, as quantum communication technology further develops, more innovative quantum communication technologies, such as quantum repeaters and quantum network coding, are expected to emerge, driving the broader application of quantum communication. As quantum communication technology continues to evolve and its application areas expand, the ecosystem of the quantum communication industry will also continue to improve. In the future, we will see the rise and growth of more startups focused on quantum communication technology, as well as increased collaboration and joint development among more upstream and downstream enterprises.

City Ranking

Rank	City/ Metropolitan Area	Rank	City/ Metropolitan Area
1	San Francisco-San Jose	11	Maryland-Washington D.C.
2	Hefei	12	Munich-Stuttgart
3	Chicago	13	Paris
4	London-Oxford-Cambridge	14	Tokyo-Tsukuba
5	New York	15	Guangdong-Hong Kong-Macao Greater Bay Area
6	Boston	16	Helsinki
7	Colorado-Denver	17	Sydney
8	Beijing	18	Zurich
9	Vancouver	19	Singapore
10	Toronto-Burnaby	20	Shanghai

Quantum technology, as a frontier field with significant potential for future technological paradigm shifts, has become a key focus of global technological strategic planning. The top five cities are San Francisco, Hefei, Chicago, London-Oxford-Cambridge, and New York. In the top 20 cities list, U.S. cities hold 6 spots, European cities occupy 4, and Asian cities take 6 spots, with 4 cities from China.

In terms of industrial scale and quantum applications, the United States is currently at the forefront of global quantum technology development, particularly in the field of quantum computing, where companies like Google, IBM, and Microsoft have developed and established quantum computing platforms. China is a leader in quantum technology within Asia, with major companies such as QuantumCTek, CIQTEK, and Origin Quantum. There are also several potential unicorn companies, including TURINGQ, QUDOOR, and HYQUBIT.

Enterprise ranking

Rank	Enterprise	Rank	Enterprise
1	IBM	11	Microsoft
2	Google	12	Atos
3	QuantumCTek	13	SEEQC
4	Quantinuum	14	IQM
5	IonQ	15	Origin Quantum
6	Hyqubit	16	PsiQuantum
7	Rigetti	17	QuantWare
8	CIOTEK	18	ORCA Computing
9	D-wave	19	Quandela
10	Xanadu	20	ColdQuanta

05
Comprehensive analysis and ranking of future industries

Deep space，low-altitude and deep sea

Definition

The space industry involves commercial activities using space technology, including space tourism, mining, manufacturing, and research. It is a high-tech, high-risk, and high-reward sector requiring support from governments, businesses, research institutions, and investors.

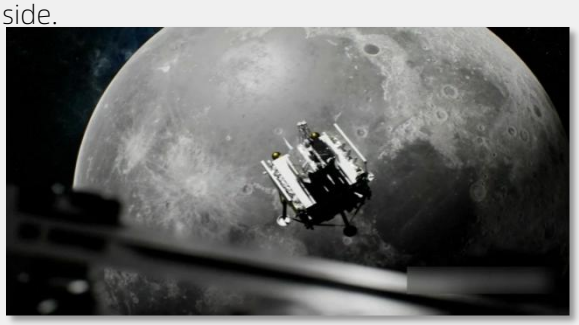
The low-altitude industry focuses on economic activities below 3,000 meters, driven by manned and unmanned aerial vehicles. It covers traditional sectors like aviation and law enforcement, as well as emerging fields like Urban Air Mobility (UAM) using eVTOLs.

The deep-sea industry encompasses commercial activities using deep-sea technology, such as resource development, research, and tourism. Despite technical challenges, its growth is essential for ocean exploration and resource utilization.

Summary of Outstanding Achievements in 2024

(1) Chang'e-6 Achieves First Ever Moon Far-Side Sample Return

On June 25, 2024, China's Chang'e-6 probe successfully completed the first-ever moon surface sample return mission, bringing back 1,935.3 grams of samples from the moon's far side.



This marks the first time in human history that samples were collected from the far side of the moon. Through analysis of the Chang'e-6 far-side samples, scientists discovered that the moon's magnetic field strength may have rebounded 2.8 billion years ago, providing the first known ancient magnetic field data from the far side of the moon and offering a crucial insight into the moon's magnetic field evolution.

(2) SpaceX's Starship 'Chopstick Rocket' Technology: A Revolutionary Leap in Space Exploration

SpaceX's "Starship" project has made significant progress, with its unique "chopstick rocket" technology gaining widespread attention and being included in *Science* magazine's top ten scientific breakthroughs of the year. This technology has revolutionary implications for future space travel and deep space exploration, potentially leading to a dramatic reduction in space transportation costs and accelerating the commercialization of space exploration.

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Comprehensive analysis and ranking of future industries

Deep space，low-altitude and deep sea

Summary of Outstanding Achievements in 2024

(3) "NASA's Europa Clipper Mission: A Historic Journey to Uncover Life's Potential on Jupiter's Moon"

On October 15, 2024, NASA's "Europa Clipper" mission successfully launched from Kennedy Space Center aboard a Falcon Heavy rocket, with an expected arrival at Jupiter's orbit in 2030. The mission aims to explore whether Jupiter's ocean moon, Europa, could potentially support life. It is NASA's largest planetary probe to date and the most heavily funded planetary exploration mission so far. The mission has profound implications for understanding the origin of life and the possibility of life in our solar system.

(4) "EHang Launches Autonomous eVTOL Flight Tests and Air Taxi Trials in Multiple Countries"

In 2024, Chinese company EHang successfully launched autonomous flight testing for its electric vertical takeoff and landing (eVTOL) aircraft and began commercial trial flights for air taxi services in select cities. The company has been conducting test operations in markets such as China, Brazil, and Thailand, providing short-distance intercity flight services. The goal is to accelerate the maturation of aerial mobility technology and gradually achieve large-scale application.

(5) Wing Launches Consumer Drone Delivery Service in Multiple Countries

In 2024, Wing (Alphabet) launched a consumer drone delivery service, covering multiple countries and regions, particularly in select cities across the United States, Australia, and Europe. The company is using autonomous drone systems to provide fast delivery of small goods such as everyday items, food, and pharmaceuticals to consumers.

(6) "China's 'Hailong' Unmanned Deep-Sea Detector Achieves Historic Exploration Milestone"

In 2024, China successfully completed the first deep-sea exploration mission with the "Hailong" unmanned deep-sea detector. The device descended to depths exceeding 10,000 meters, collecting a wealth of critical deep-sea data, including biological samples, mineral distribution, and the physical and chemical characteristics of the deep-sea environment. This mission marks a significant breakthrough in China's deep-sea exploration technology, particularly in high-precision detection and data collection in extreme deep-sea environments.

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Comprehensive analysis and ranking of future industries

Deep space，low-altitude and deep sea

Future development trends

Deep space

- Efficient Propulsion Technology: To enable long-distance deep space exploration, traditional chemical propulsion systems will gradually be replaced by more efficient and energy-saving propulsion technologies. Electric propulsion systems, such as ion propulsion, will become mainstream due to their high energy efficiency, making them ideal for long-term, remote deep space missions. Additionally, nuclear propulsion and solar sail technologies are under development, which will allow spacecraft to travel faster through space.

- Deep Space Communication Technology: Due to the vast distances of deep space, communication delays are significant, and traditional radio communication systems are increasingly inadequate. Laser communication technology, with its high data transmission rate, is becoming one of the dominant technologies for future deep space communication. Quantum communication is also actively being developed, offering high security and resistance to interference.

- Deep Space Resource Utilization: With advancing technology, the extraction of deep space resources, such as asteroid mining and the exploitation of lunar and Martian resources, will become an important focus for the future. Emerging technologies will enable us to extract and utilize mineral resources from these celestial bodies, potentially providing critical resources for Earth and alleviating resource shortages on our planet.

Low-altitude

- Satellite Constellations & Global Communication: Low Earth orbit satellite networks like Starlink and OneWeb will transform global internet access, offering efficient, low-latency broadband worldwide with smaller, cost-effective satellites.

- Drones & eVTOL Aircraft: Drones will expand beyond logistics into urban air mobility, air taxis, and agriculture. eVTOL aircraft will revolutionize short-range flights, easing urban traffic congestion.

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Comprehensive analysis and ranking of future industries

Deep space，low-altitude and deep sea

Future development trends

Deep sea

- Autonomous Underwater Vehicles (AUVs) & Underwater Robots: AUVs and remotely operated vehicles (ROVs) will continue to evolve, becoming more intelligent and capable of autonomously performing complex tasks such as seafloor exploration, resource collection, and environmental monitoring. Equipped with precise sensors and AI algorithms, these devices will carry out deep-sea research without human intervention.

- Underwater Resource Extraction & Deep-Sea Mining: As global demand for resources increases, deep-sea mining will become a key focus. Future technologies will enable more environmentally-friendly extraction of rare metals, minerals, and other essential resources from the ocean floor, fueling global economic growth.

- Underwater Communication & Data Transmission: The underwater environment presents significant challenges for signal transmission, as traditional radio waves have a very limited range. Future underwater communication will increasingly rely on advancements in acoustic technology and may even utilize optical communication for faster transmission speeds. Additionally, efficient data processing and transmission technologies will make real-time feedback from deep-sea exploration more feasible.

City Ranking

Rank	City/ Metropolitan Area	Rank	City/ Metropolitan Area
1	New York	11	Dubai
2	Washington DC-Baltimore	12	Sydney
3	Los Angeles	13	London-Oxford-Cambridge
4	Beijing	14	Toronto
5	Shanghai	15	San Francisco-San Jose
6	Paris	16	Seoul
7	Moscow	17	Singapore
8	Tokyo-Yokohama	18	Hefei
9	Munich-Stuttgart	19	Zurich
10	Bangalore	20	Amsterdam

In 2024, several cities excelled in deep-sea, low-altitude, and deep-space research, thanks to strong government investment, leading research institutions, and active international collaboration. The U.S. ranked first, with New York, Washington D.C., and Los Angeles playing key roles in these fields. The U.S. has long been a global leader in aerospace and space exploration, bolstered by top institutions like NASA and JPL. Beijing and Shanghai ranked 4th and 5th, reflecting China's investment in space exploration and low-altitude flight technology, driven by CNSA.

Other notable cities include Moscow, Tokyo, Munich, and Bangalore, excelling in aerospace, deep-sea, and low-altitude flight technologies. UAE and Israel, with strategic investments, have also become prominent in low-altitude and drone technologies, particularly in Dubai.

Overall, the ranking highlights the dominance of the U.S. and China, reflecting their substantial investments in aerospace and technological infrastructure. The rise of emerging players like India, UAE, and Israel signals a shifting global landscape in these fields.

Enterprise ranking

Rank	Enterprise	Rank	Enterprise
1	SpaceX	11	DJI (Da-Jiang Innovations)
2	NASA	12	Roscosmos
3	CNSA	13	State Oceanic Administration of the People's Republic of China
4	ESA	14	Volocopter
5	JAMSTEC	15	CNES
6	GEOMAR Helmholtz Centre for Ocean Research Kiel	16	UAESA
7	EHang Intelligent	17	ISRO
8	WHOI	18	German Aerospace Center (DLR)
9	SIO	19	JAXA
10	Leshi Information	20	The Boeing Company

05
Comprehensive analysis and ranking of future industries

Artificial intelligence (AI)

Definition

Artificial intelligence (AI) is the theory and development of computer systems capable of performing tasks that historically required human intelligence, such as speech recognition, decision-making, and pattern recognition. AI is a broad term that encompasses various technologies, including machine learning, deep learning, and natural language processing. The AI industry chain is generally divided into three layers: the foundational layer, the technological layer, and the application layer. The foundational layer lays the groundwork for AI industries in areas such as networks, algorithms, hardware deployment, and data collection. The technological layer focuses on building technical paths to simulate human intelligence-related characteristics. The application layer integrates one or more types of AI foundational technologies, creating software and hardware products or solutions tailored to specific application scenarios.

Summary of Outstanding Achievements in 2024

(1) Large Models and Multimodal Integration

In 2024, OpenAI launched the GPT-4o version, which doubled the speed compared to its predecessor, reduced the price by 50%, and increased the rate limit by five times. OpenAI also introduced Sora, a text-to-video program capable of generating Hollywood-like, imaginative videos from simple text descriptions. This marks a leap in AI content generation from single-modal text to multi-modal content generation.

Meanwhile, Meta released the Llama 3.1 model with 405 billion parameters, which was the world's largest open-source AI model at the time. It could handle tasks such as complex mathematical problems and multi-language translation. In September of the same year, Meta launched the Llama 3.2 model, emphasizing openness and customizability. It included medium and small-sized visual models suitable for edge and mobile devices, as well as lightweight pure-text models.

The rise of multi-modal AI models became an undeniable trend, with Google releasing the Gemini 2.0 model, which achieved a technological breakthrough across several iterations and surpassed GPT-4o in some areas. Models like Claude-3.5 also reached performance levels comparable to GPT-4o in reasoning, mathematics, and multi-language processing. Additionally, the French AI startup Mistral launched the first multi-modal AI large model, Pixtral 12B, showcasing the immense potential of multi-modal AI models in handling complex tasks.

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Comprehensive analysis and ranking of future industries

Artificial intelligence (AI)

Summary of Outstanding Achievements in 2024

(2) Small Language Models Gain Attention

Although large language models (LLMs) continue to dominate the headlines, interest in small language models (SLMs) has been growing in 2024. Companies like Microsoft are exploring SLMs such as Phi and Orca, indicating that efficient, specialized models can sometimes outperform large models in specific tasks. This trend toward more compact, resource-efficient AI models is expected to lead to broader accessibility and application.

(3) Breakthroughs in Self-Supervised Learning

Self-Supervised Learning (SSL) made significant progress in 2024, enabling AI to autonomously learn important features from vast amounts of unlabeled data, even in the absence of extensive annotated datasets. This technology achieved breakthroughs, particularly in Natural Language Processing (NLP) and Computer Vision (CV), significantly improving model learning efficiency and reasoning abilities.

In the field of NLP, self-supervised learning made remarkable strides, especially in understanding context, semantics, and even sentiment analysis, without relying on expensive annotated datasets.

In 2024, OpenAI enhanced the GPT-4 model with self-supervised learning techniques, improving its ability to understand context, conduct sentiment analysis, and generate human-like dialogue, with particularly impressive performance on low-resource languages. This model no longer requires annotated data for each new application. In the field of CV, self-supervised learning reduced dependence on labeled data and improved the accuracy of image recognition and object detection. In 2024, Baidu enhanced its autonomous driving vision perception system using self-supervised learning techniques. By leveraging millions of hours of unlabeled driving footage, the model became more accurate at detecting pedestrians, vehicles, and traffic signs, thereby improving the system's adaptability in complex environments, reducing the need for manual annotations, and accelerating the development of autonomous driving technology.

(4) Initial Implementation of a Global Governance Framework for AI Ethics and Transparency

Multiple countries and international organizations have introduced ethical standards and regulations regarding the use of AI, emphasizing the transparency, fairness, interpretability, and safety of AI algorithms, the European Union's Artificial Intelligence Act has entered the implementation phase, focusing on regulating high-risk AI applications and outlining specific ethical requirements. At the same time, an increasing number of companies and academic institutions around the world are actively exploring ways to make AI models more transparent, interpretable, and reduce bias and discrimination.

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Comprehensive analysis and ranking of future industries

Artificial intelligence (AI)

Future development trends

Technological Innovation and Modexl Evolution

- Widespread Adoption and Deepening of Multimodal Large Models: AI models are gradually evolving towards multimodal capabilities, integrating various types of data such as text, images, videos, and audio to achieve more comprehensive information understanding and interaction. The unified multimodal technical approach has become mainstream, enabling end-to-end input and output by processing multimodal data from the very beginning of training. Multimodal large models will play a significant role in foundational and applied sciences, including biomedical research, meteorology, material discovery, life simulations, and energy, opening up new research directions.

- Significant Improvement in Reasoning and Logical Inference Capabilities: The reasoning capabilities of AI models are continuously optimized, especially on resource-limited devices such as smartphones and PCs, with AI-native applications being deployed through algorithm acceleration and hardware optimization techniques.

- Integration of Hardware Optimization and Emerging Technologies: The development of specialized processors and edge computing technologies brings AI processing closer to the data source, reducing latency and bandwidth usage. Meanwhile, emerging technologies like quantum computing hold the potential to provide significant computational leaps for AI, addressing complex problems that traditional computers struggle with.

- The Crucial Role of Synthetic Data: Synthetic data has become a key catalyst in the iteration and deployment of large models, reducing the cost of manual governance and annotation, alleviating the dependency on real data, and simultaneously improving the diversity and quality of data.

Application Expansion and Market Dynamics

- Widespread Adoption of Intelligent Agents and Autonomous Decision-Making: Intelligent agents are capable of autonomously perceiving their environment, making decisions, and taking actions, thereby improving work efficiency and daily convenience. In industries such as manufacturing and services, intelligent agents have shown tremendous application potential. As a key model for product deployment, Agentic AI will further integrate into work and life scenarios, offering intelligent services to meet diverse user needs.

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Comprehensive analysis and ranking of future industries

Artificial intelligence (AI)

Future development trends

Application Expansion and Market Dynamics

- Widespread Use and Evolution of Generative AI: Generative AI creates new content in fields like text, images, and music, supporting the creative industries and data augmentation. With ongoing technological advancements, generative AI is no longer limited to chatbots but is being applied in a broader range of software and services, including data summarization, content creation, and personalized recommendations. This provides strong support for innovation in related industries.

- Deep Industry Integration and Transformation: In sectors such as smart manufacturing, healthcare, finance, education, retail, and transportation, AI technologies are playing an increasingly crucial role. By leveraging AI, businesses can improve production efficiency, optimize operational processes, and enhance service quality, thereby boosting market competitiveness.

Regulation, Ethics, and Social Impact

- Continuous Improvement of AI Security Governance Systems: The scaling of large models has led to the emergence of new phenomena, but the unpredictability and feedback loops inherent in complex systems pose challenges to traditional safety mechanisms. Ongoing progress in foundational models' autonomous decision-making presents potential risks of loss of control. Therefore, new regulatory methods need to be introduced, balancing industry development with risk management through both technological oversight and human regulation.

- Regulatory Development and Ethical Standards: As AI technology becomes more widely applied, regulatory development and ethical standards have become pressing issues. To ensure the healthy and sustainable development of technology, more economies will implement AI governance legislation. These regulations will focus on issues such as data privacy protection and algorithmic bias, ensuring the fair and just application of AI technology. At the same time, AI development and application will place greater emphasis on ethics and intellectual property rights, avoiding potential social risks.

City Ranking

Rank	City/ Metropolitan Area	Rank	City/ Metropolitan Area
1	San Francisco-San Jose	11	Tokyo-Yokohama
2	Los Angeles	12	Washington DC-Baltimore
3	London-Oxford-Cambridge	13	Guangdong-Hong Kong-Macao Greater Bay Area
4	Beijing	14	Shanghai
5	New York	15	Hamburg
6	Hangzhou	16	Toronto
7	Paris	17	Amsterdam
8	Berlin	18	Bangalore
9	Shenzhen	19	Singapore
10	Sydney	20	Barcelona

The San Francisco Bay Area remains a global AI leader, with Silicon Valley housing top companies like Google and OpenAI, and prestigious institutions like Stanford and UC Berkeley. Its influence in AI innovation and application is unmatched.

London has made significant progress in AI, especially in ethics, social impact, and cross-industry applications, driven by companies like DeepMind. Paris also excels in AI ethics and smart city technologies.

In Asia, Beijing, Hangzhou, Shenzhen, Shanghai, and Tokyo are key players in AI research and application. Beijing leads in smart manufacturing, while Hangzhou and Shenzhen drive AI hardware and robotics. Tokyo stands out in robotics and autonomous driving.

Overall, the US and China dominate AI development, with the Bay Area's strong capital and talent, and China's policy-driven AI growth. Other European and Asian cities like London, Paris, and Tokyo remain important contributors.

Enterprise ranking

Rank	Enterprise	Rank	Enterprise
1	Open AI	11	IBM
2	Google	12	AMD
3	Anthropic	13	Moonshot
4	Microsoft	14	Alibaba
5	Meta	15	Huawei
6	DeepSeek	16	LG
7	Tesla	17	Samsung
8	ByteDance	18	Naver
9	Amazon	19	Aleph Alpha
10	Tencent	20	Cerebras

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Comprehensive analysis and ranking of future industries

Clean Energy

Definition

Clean energy refers to energy sources that do not produce pollutants during production and use or can be directly applied to production and daily life. These energy sources are typically environmentally friendly, characterized by low emissions and minimal pollution. Clean energy primarily includes two categories: renewable energy and the clean utilization of non-renewable energy. Renewable energy includes hydropower, wind power, solar energy, biomass energy, geothermal energy, and tidal energy; while the clean utilization portion of non-renewable energy includes nuclear energy and clean fossil fuels.

Summary of Outstanding Achievements in 2024

(1) LONGi Green Energy sets a record with the efficiency of its monocrystalline silicon-perovskite tandem solar cell

LONGi Green Energy has developed a monocrystalline silicon-perovskite tandem solar cell with a conversion efficiency of 34.6%, setting a new world record. This achievement was made possible through the optimization of the electron transport layer deposition process, the introduction of high-efficiency defect passivation materials, and the design and development of high-quality interface passivation structures, resulting in a 0.7% absolute increase in cell efficiency.

(2) Princeton Explores Achieving AI-Controlled Nuclear Fusion

A research team from Princeton University's Plasma Physics Laboratory published an article in "Nature", exploring the use of AI to predict plasma disruptions 300 milliseconds in advance and take preventive measures to avoid this instability, helping address the challenges of controlling nuclear fusion.

(3) The world's first 300-megawatt compressed air energy storage power station has been completed

The Institute of Engineering Thermophysics at the Chinese Academy of Sciences has successfully overcome key technologies in full operating condition design, integrated control technology, and supercritical compact thermal energy storage heat exchangers for 300-megawatt advanced compressed air energy storage systems. It has established the world's largest and most comprehensive integrated R&D platform for compressed air energy storage systems.

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Comprehensive analysis and ranking of future industries

Clean Energy

Future development trends

(1) The transition from "centralized" to "distributed" and the evolution from single energxy sources to integrated energy systems

In the future, China's energy sector will present a pattern of coexistence between centralized and distributed systems. Centralized energy bases will continue to focus on large-scale energy storage technologies and long-distance transmission technologies to meet the nationwide demand for large-scale energy allocation. Distributed energy, on the other hand, will rely on smart grids and digital technologies to realize localized and flexible energy consumption structures. At the same time, clean energy will gradually form a collaborative development pattern of wind, solar, hydro, nuclear, and hydrogen energy. Currently, the hydrogen energy industry chain is accelerating its development, and technological breakthroughs in hydrogen production and storage will inject new vitality into the zero-carbon energy system. In addition, new energy storage technologies, such as solid-state batteries and flow batteries, are helping to achieve flexible adjustment and efficient utilization of energy resources.

(2) The commercialization process of Small Modular Reactors (SMRs) is accelerating

Small Modular Reactors (SMRs) are nuclear reactor technologies with a power output of less than 300 megawatts. SMR technologies include water-cooled reactors, high-temperature gas-cooled reactors, liquid metal fast reactors, and molten salt reactors.

Currently, there are only three SMRs in operation worldwide, located in China and Russia. Japan is also conducting significant research and is committed to promoting the restart of nuclear power. Among them, Russia's Akademik Lomonosov floating nuclear power plant is the only operational floating nuclear power plant in the world. It is equipped with two KLT-40S small modular reactors (SMRs), each with an electrical capacity of 35 megawatts, for a total electrical capacity of 70 megawatts and a thermal capacity of 150 megawatts. The plant first connected to the grid in December 2019 and began commercial operations in May 2020. China's "Linglong One" is the world's first third-generation light-water SMR, with an electrical power output of 125 MW, and it is the first land-based commercial SMR. China's HTR-PM demonstration SMR is the country's first SMR project, consisting of two 100 MW reactor modules, each with a thermal power of 250 MW. It achieved a key milestone in December 2021 and has been put into operation.

As a flexible and reliable low-carbon energy solution, SMRs can complement renewable energy sources and support the global energy transition. Their applications include grid power supply, distributed thermal energy supply, industrial heating, hydrogen production, and desalination, among others. SMRs are also suitable for industrial parks, remote villages, and isolated areas, providing stable power and thermal energy supply to these regions.

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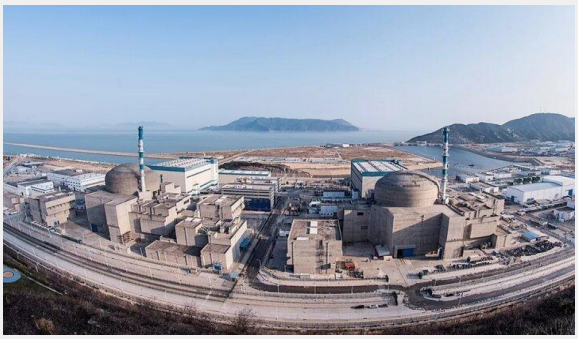
Comprehensive analysis and ranking of future industries

Clean Energy

Future development trends

(3) Fourth-generation nuclear technology represents the future direction of nuclear energy development

Fourth-generation nuclear power refers to the next-generation reactors currently under development, which feature significant innovations in reactor concepts and fuel cycles. The main characteristics of this technology include high safety and reliability, low waste generation, better economic efficiency, multifunctionality, and the prevention of nuclear proliferation. This technology includes fast neutron reactors, thorium-based reactors, and high-temperature gas-cooled reactors. With the development of nuclear energy technology, fast neutron reactors are considered to have significant development advantages, with sodium-cooled fast reactors and lead-cooled fast reactors emerging as two highly promising reactor types for the fourth generation. France and Russia are leading the way in fast neutron reactor technology. China has built the world's first commercial high-temperature gas-cooled reactor and thorium-based molten salt reactor demonstration projects. Countries such as the United States and Canada are also accelerating the research and testing of fourth-generation nuclear energy technologies.



(4) The commercialization of hydrogen energy is accelerating, marking the dawn of a new era

As global attention to sustainable development and environmental protection grows, governments worldwide are implementing policies to support the development of the hydrogen energy industry. For example, the European Union has proposed a "Hydrogen Energy New Policy," with plans to install 40GW of electrolyzer capacity by 2030; the United States is supporting hydrogen energy development through tax credits under the Inflation Reduction Act (IRA); and China has also listed hydrogen energy as one of its strategic emerging industries.

In terms of technological advancements and industrial upgrades, with continuous breakthroughs in clean hydrogen production technologies such as water electrolysis, the production capacity of green hydrogen will significantly increase. As hydrogen storage and transportation remain key bottlenecks in the industry's development, the ongoing research and application of new storage and transportation technologies, such as liquid hydrogen and solid-state hydrogen storage, will effectively address these challenges. Moreover, fuel cells, as a key technology for hydrogen energy applications, will drive the rapid growth of the hydrogen industry as their performance improves and costs decrease. The continuous development and application of new fuel cell technologies, such as proton exchange membrane fuel cells and solid oxide fuel cells, will provide more diversified application scenarios and broader market opportunities for the hydrogen industry.

City Ranking

Rank	City/ Metropolitan Area	Rank	City/ Metropolitan Area
1	Sao Paulo	11	Boston
2	San Francisco-San Jose	12	Tokyo-Yokohama
3	Moscow	13	Los Angeles
4	Vancouver	14	Malmo
5	London-Oxford-Cambridge	15	Shanghai
6	Munich-Stuttgart	16	Sydney
7	Heidelberg	17	Amsterdam
8	Paris	18	Berlin
9	Hefei	19	Changzhou
10	Chiba	20	Guangdong-Hong Kong-Macao Greater Bay Area

In the field of clean energy, Europe made early investments and has a relatively high level of technology. As seen in the rankings, European cities occupy 7 positions in the top 20. Following Europe, China and the United States also maintain a global leading position in clean energy usage and technological research and development, occupying four and three positions, respectively, in the top 20 city rankings.

Enterprise ranking

Rank	Enterprise	Rank	Enterprise
1	Vestas	11	Acciona
2	CNNC	12	Renaissance Fusion
3	Commonwealth Fusion Systems	13	Fusion Energy Institute
4	TotalEnergies	14	Proxima Fusion
5	LG Energy	15	Shellplc
6	Helion Energy	16	Enel
7	CGN	17	Ex- Fusion
8	First Solar	18	Startorus Fusion
9	Marvel Fusion	19	Valero
10	General Fusion	20	Thales

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Comprehensive analysis and ranking of future industries

Embodied Intelligence

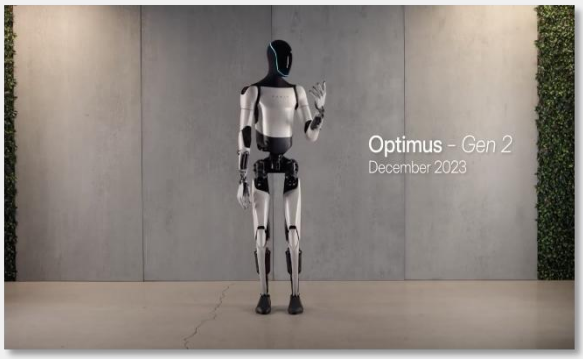
Definition

Embodied Intelligence refers to the idea that intelligence is not solely a product of the brain or mind, but rather arises from the interaction between an organism's body and its environment. This concept emphasizes that cognitive processes are deeply intertwined with physical experiences, sensory perception, and motor actions. In embodied intelligence, the body plays an active role in shaping and facilitating decision-making, problem-solving, and learning. It suggests that intelligence is distributed across the body and the environment, rather than being contained within a single cognitive system. This concept is often applied in fields such as robotics, cognitive science, and artificial intelligence, where physical actions or behaviors are used to enhance cognitive abilities and learning.

Summary of Outstanding Achievements in 2024

(1) New types of humanoid robots are emerging continuously

- Tesla has released the Optimus 2 humanoid robot, which features a 30% increase in walking speed and is equipped with more advanced tactile sensing capabilities. This design not only enhances the robot's flexibility and precision but also broadens its potential applications in various fields such as manufacturing, logistics, and elderly care.



- Boston Dynamics has bid farewell to the hydraulic version of the Atlas humanoid robot and introduced the fully electric Atlas. The new version of Atlas now uses electric drive, offering a wider range of motion and the ability to perform more complex tasks. The hydraulic version of Atlas featured innovations in its movement structure, enabling it to perform actions such as push-ups and handstands, showcasing breakthroughs in flexibility and precision for humanoid robots. This highly lifelike humanoid design holds significant application potential in industries such as manufacturing, military, and rescue operations.

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Comprehensive analysis and ranking of future industries

Embodied Intelligence

Summary of Outstanding Achievements in 2024

- NVIDIA CEO Jensen Huang unveiled the humanoid robot foundation model GR00T (short for "General-Purpose Robot 00 Technology") at GTC 2024. GR00T is designed to serve as a starting point for humanoid robots performing specific tasks. Robots powered by GR00T will be capable of understanding natural language, observing and imitating human behavior, and rapidly learning coordination, dexterity, and other skills to navigate, adapt, and interact in the real world.
- The Yushu G1 humanoid robot can be equipped with the Dex3-1 force-controlled dexterous hand, capable of performing routine tasks such as cracking walnuts and moving heavy objects, as well as handling more delicate operations like opening soda bottles and welding. The Kepler K2 has a single-hand load capacity of 15 kilograms and is equipped with flexible sensors with 96 contact points on each fingertip, enabling high-precision environmental perception and the ability to carry out fine manipulations.

(2) The commercialization of humanoid robots is accelerating

- Humanoid robots enter factory training: UBTECH's Walker S series has been applied to production lines of several automakers, including Dongfeng Liuzhou Motors, BYD, and Geely, to assist in efficiently completing production tasks. At the same time, companies like Leju, Zhiyuan, Galaxy General, and Yushu are also collaborating with automakers to test and explore humanoid robot applications in factories. Tesla's second-generation Optimus began factory training in May, with plans to begin mass production and sales by the end of 2025.
- Commercial mass production begins: Zhiyuan Robotics has officially launched the commercial mass production of general-purpose robots, with an annual production target of 962 units. Fourier's general-purpose humanoid robot GR-1 has delivered over 100 units as of October.

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Comprehensive analysis and ranking of future industries

Embodied Intelligence

Future development trends

(1) Stronger emotional and social capabilities

In the future, humanoid robots will possess higher emotional recognition and expression capabilities. This means that robots will not only be able to recognize human emotions (such as anger, joy, anxiety, etc.) but also respond accordingly, engaging in emotional communication with humans through voice, facial expressions, body language, and other means. This will enable humanoid robots to be more adaptable and personable in fields such as education, healthcare, and customer service. Additionally, through natural language processing (NLP) and multimodal perception, future humanoid robots will be able to engage in more natural and fluid conversations and interactions, understanding complex contexts and emotional changes, making them more "approachable" and easier to accept in human society.

(2) Higher autonomy and intelligence

In the future, humanoid robots will possess higher emotional recognition and expression capabilities. This means that robots will not only be able to recognize human emotions (such as anger, joy, anxiety, etc.) but also respond accordingly, engaging in emotional communication with humans through voice, facial expressions, body language, and other means.

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(3) Expansion of human-robot collaboration and industry applications

Humanoid robots will play an increasingly important role in various industries, particularly in areas such as industrial automation, healthcare, education, and home services. They will be able to collaborate with humans to complete various tasks, take on dangerous or repetitive work, and provide personalized services and care. This human-robot collaboration will not only improve work efficiency but also reduce the human workload. Especially in an aging society, robots will become an essential tool for assisting the daily lives of the elderly.

(4) Stronger physical adaptability and flexibility

Future humanoid robots will possess more refined and efficient movement capabilities. With high-precision sensors and intelligent control systems, they will be able to perform flexible movements in complex environments, such as walking on uneven terrain, climbing stairs, running, and even jumping.

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Comprehensive analysis and ranking of future industries

Embodied Intelligence

Future development trends

These robots will not only mimic but potentially surpass human mobility, enabling them to execute high-risk and high-precision tasks.

To adapt to different environments and tasks, future humanoid robots will be able to change their form more flexibly, enhancing their physical adaptability. For example, through modular design, robots will be able to work more efficiently in various scenarios by attaching specialized tools for repairs, maintenance, and other tasks. Additionally, they may have the capability to replace certain components as needed, ensuring long-term operational efficiency.

(5) Challenges of ethics, safety, and privacy issues

As humanoid robots become more widespread, addressing the ethical, privacy, and safety challenges brought by robotic technology will become a core issue. Ensuring that robots interact with humans in a fair and safe manner, while avoiding privacy violations and potential harm, will be a key concern for regulatory and legal frameworks worldwide. As technology advances, global ethical and safety standards will be gradually refined to ensure the security and reliability of humanoid robots in serving humanity.

City Ranking

Rank	City/ Metropolitan Area	Rank	City/ Metropolitan Area
1	Boston	11	Beijing
2	Hangzhou	12	Barcelona
3	Los Angeles	13	Milan
4	Seoul	14	Amsterdam
5	Shenzhen	15	Toronto
6	Paris	16	Tokyo-Yokohama
7	London-Oxford-Cambridge	17	Sydney
8	Berlin	18	San Francisco-San Jose
9	Singapore	19	Helsinki
10	Shanghai	20	Sao Paulo

In 2024, the United States and China dominate global academic and technological research in humanoid robotics, reflecting their deep expertise and strong innovation. Boston remains a global leader with Boston Dynamics' Atlas and research from institutions like Harvard. Meanwhile, Hangzhou, Shanghai, and Beijing drive China's rapid rise, fueled by government support and market demand, with advancements in smart homes, healthcare, and AI applications.

The U.S. maintains its dominance through cities like Boston and Los Angeles, while Tokyo, despite its singular ranking, remains influential due to its strong robotics foundation. Overall, the global robotics race is led by the U.S. and China, with their key cities shaping future breakthroughs and applications.

Enterprise ranking

Rank	Enterprise	Rank	Enterprise
1	Boston Dynamics	11	Hyundai Robotics
2	Tesla	12	Toyota
3	Agility Robotics	13	Engineered Arts
4	Unitree Robotics	14	Robotis
5	Honda	15	PAL Robotics
6	Figure AI	16	Miko
7	UBTECH	17	Mujin
8	Sanctuary AI	18	Xiaomi
9	Apptronik	19	Neura Robotics
10	Fourier Intelligence	20	Shadow Robot Company

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Comprehensive analysis and ranking of future industries

Neuroscience and neuromorphic intelligence

Definition

Neuroscience and brain-inspired intelligent technology, two cutting-edge fields, are increasingly converging and complementing each other, becoming major research hotspots in the global scientific community in recent years. Neuroscience provides important scientific evidence and clinical guidance for the effective diagnosis and treatment of brain diseases through in-depth analysis of the neural basis of various brain functions. At the same time, the findings in neuroscience offer inspiration and insight for brain-inspired research. Brain-inspired intelligence is a type of machine intelligence driven by the brain's neural and cognitive mechanisms, achieved through computational modeling and the collaborative use of software and hardware. It features brain-like information processing, human-like cognitive behaviors, and intelligence levels that meet or exceed human capabilities.

Summary of Outstanding Achievements in 2024

(1) 3D Printing of Functional Human Brain Tissue

American scientists have successfully 3D printed functional human brain tissue for the first time. This tissue can grow and function like traditional brain tissue. This breakthrough is of significant importance for studying the brain and treating various neurological and neurodevelopmental diseases, such as Alzheimer's and Parkinson's diseases.

(2) The first human gene-edited pig kidney transplant has been completed

In March 2024, a surgical team at Massachusetts General Hospital completed the world's first live human pig kidney transplant. The transplant was approved under the U.S. Food and Drug Administration (FDA)'s "compassionate use" authorization.

(3) Neuralink has completed the first human brain chip implantation

On January 28, 2024, Elon Musk's brain-machine interface company, Neuralink, completed the first human brain chip implantation. In March, Musk livestreamed the progress of a man who had been paralyzed from the neck down for eight years due to a diving accident. The man was now able to control a mouse and play games online, including chess, with his thoughts. In August, Neuralink successfully implanted the device into a second patient, with positive results post-surgery. This achievement signifies that the science fiction concept of "thought control" is gradually becoming a reality, heralding the potential arrival of a new era in human-machine interaction.

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Comprehensive analysis and ranking of future industries

Neuroscience and neuromorphic intelligence

Future development trends

(1) The Brain-Computer Interface (BCI) market is experiencing rapid growth

The application scope of BCI technology is continuously expanding, covering fields such as medical rehabilitation, entertainment, and education. For example, through BCI technology, paralyzed patients can control external devices with their thoughts. In the future, BCI will enable bidirectional communication, where AI not only decodes neural signals but also stimulates the brain to restore lost functions, such as accelerating motor recovery for stroke patients through AI-enhanced BCI.

(2) The deep integration of AI and brain science

Explainable AI (XAI): Future AI systems will not only generate accurate predictions but also explain their reasoning processes. For example, XAI models can visualize the neural activity patterns that lead to specific diagnoses, enhancing trust in clinical applications.

Generative AI: Models such as Generative Adversarial Networks (GANs) and Transformers will play a key role in neuroscience, for example, by generating synthetic fMRI data to train AI systems, thereby improving the robustness of models.

(3) Advancements in Neural Decoding Technology and Breakthroughs in Brain-like Chips

Technologies such as brain imaging, brain-machine interaction, and biosensing will continue to upgrade, allowing for more accurate and in-depth analysis of the brain's neural mechanisms. For example, more advanced brain imaging equipment will capture brain activity with higher resolution, providing more precise data for building brain-like intelligent models. Research on brain-like chips with non-Von Neumann architectures, such as spiking neural network chips and memristors, will make greater progress, achieving higher computational efficiency and lower energy consumption. This could lead to the development of more powerful, highly integrated brain-like chips, driving the advancement of brain-like intelligent hardware.

City Ranking

Rank	City/ Metropolitan Area	Rank	City/ Metropolitan Area
1	Boston	11	New York
2	San Francisco-San Jose	12	Kyoto-Osaka-Kobe
3	London-Oxford-Cambridge	13	Hangzhou
4	Beijing	14	Washington DC-Baltimore
5	Shanghai	15	Guangdong-Hong Kong-Macao Greater Bay Area
6	Tokyo-Yokohama	16	Basel
7	Paris	17	Los Angeles
8	Zurich	18	Berlin
9	Toronto	19	Munich-Stuttgart
10	Seoul	20	Melbourne

Global progress in Neuroscience and neuromorphic intelligence has been made in both hardware and software. Hardware advancements, such as brain-machine interfaces, nano "optical tweezers," and real-time decoding chips, offer new research tools, while software innovations like neural mapping and brain simulation models are emerging.

The U.S. is a global leader, with key players like Intel, HP, Numenta, Vicarious, and Neuralink. It holds five slots in the top twenty cities, dominating the field.

China, while starting later, has rapidly caught up, particularly in brain-like chips, brain-like computers, and brain mapping. It ranks second globally, with four cities in the top twenty.

Enterprise ranking

Rank	Enterprise	Rank	Enterprise
1	Neuralink	11	Innatera
2	Synchron	12	Neura Matrix
3	BrainCo	13	Blackrock Neurotech
4	Cogitat	14	Neuro Xess
5	Neurcle	15	Lifescapes
6	BrainUp Technology	16	Next Mind
7	Numenta	17	Flow Neuroscience
8	Theranica	18	DeepMind
9	Cyberkinetics	19	Vicarious
10	Neurosoft Bioelectronics	20	MicroPort Neuro Tech

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Comprehensive analysis and ranking of future industries

Advanced Connectivity

Definition

Wireless network connectivity is a fundamental component of social life. Although 5G networks offer inherent flexibility, the development and transformation of society and the economy will present challenges that 5G may not be able to address. We need to further expand into the 6G era.

With the advancement of each generation of communication technologies, the focus of networks has continuously evolved. The focus of the 5G era is on connecting the Internet of Things (IoT) and industrial automation systems, while the 6G era aims to integrate physical, digital, and human experiences. 6G will involve the organic fusion of terrestrial mobile communications with high, medium, and low Earth orbit satellites, requiring heterogeneous access via satellites, launch platforms, drones, and ground-based cell towers. This will meet diverse deployment scenarios and business needs, enabling seamless global coverage and access for anyone, anywhere, at any time. Among these, low Earth orbit broadband satellite internet, with its wide coverage, high bandwidth, low latency, and resistance to regional limitations, will become a key component of 6G.

Summary of Outstanding Achievements in 2024

(1) The commercial trials of 6G technology have been launched

In 2024, several countries and regions around the world began the initial commercial trials of 6G technology. Notably, in China and Finland, pilot tests for 6G networks were conducted in multiple cities. These test networks achieved ultra-high-speed data transmission rates of 1Tbps, significantly lower latency than 5G, and supported large-scale device connectivity.

In China, the construction of 5G infrastructure laid a solid foundation for the arrival of 6G. In 2024, China began testing 6G application scenarios, including ultra-high-definition video, smart cities, and smart healthcare.

Finland's Nokia, in collaboration with European research institutions, completed the world's first 6G-based communication test in 2024, showcasing the future importance of 6G networks in global communications.

(2) Global Breakthroughs in Quantum Communication

In 2024, significant progress was made in quantum communication technology worldwide, particularly in the field of Quantum Key Distribution (QKD). China's Mozi quantum satellite successfully achieved long-distance quantum communication with multiple ground stations around the world, breaking through the previous bottleneck where quantum communication was limited by ground fiber optics.

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Comprehensive analysis and ranking of future industries

Advanced Connectivity

Summary of Outstanding Achievements in 2024

In 2024, Chinese scientists successfully conducted the first application test of Quantum Key Distribution (QKD) technology in extreme environments, such as extreme temperatures and high radiation. This breakthrough paves the way for global coverage and commercialization of quantum communication networks. This advancement ensures that quantum encrypted communication will offer unbreakable security in the future, further revolutionizing sectors like finance, military, and government communications.

(3) Global Coverage of Low Earth Orbit (LEO) Satellite Internet

In 2024, SpaceX's Starlink project and companies like OneWeb further expanded the application of Low Earth Orbit (LEO) satellites, successfully achieving global internet coverage, especially in remote regions and oceans. SpaceX completed the expansion of its global network in 2024, providing low-latency, high-speed internet connections that transformed education, healthcare, and business activities in remote areas. This achievement not only broke the limitations of traditional communication infrastructure but also provided unprecedented internet access to billions of people worldwide. Starlink has also partnered with governments in India and several African countries, planning to offer affordable network services to rural areas in these regions in the coming years.

(4) The Preliminary Application of Terahertz Communication Technology

In 2024, a joint experimental team led by the Purple Mountain Observatory of the Chinese Academy of Sciences successfully achieved kilometer-level terahertz wireless communication transmission of high-definition video signals based on superconducting receivers on the Qinghai-Tibet Plateau. This marks the first time globally that high-sensitivity terahertz superconducting receiver technology has been successfully applied in long-distance wireless communication systems. The experiment achieved the longest distance for terahertz wireless communication transmission to date in the frequency band above 0.5 THz.

At the European Microwave Week (EuMW 2024) held in Paris, Rohde & Schwarz demonstrated the concept verification of a 6G wireless data transmission system based on photon terahertz communication links. This system, based on frequency comb technology, operates at carrier frequencies significantly exceeding 500 GHz and showcased an ultra-stable, tunable terahertz system for 6G wireless communication.

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Future development trends

(1) High-Frequency Bands and Ultra-Wideband Communication (6G and Beyond)

Future communication technologies will move towards higher frequency bands, with 6G extending to the 0.1-10 terahertz (THz) frequency range, enabling ultra-high speeds (over 1 Tbps) and ultra-large bandwidths to support cutting-edge scenarios like holographic communication and the metaverse. Meanwhile, intelligent reconfigurable surface (RIS) technology will dynamically control the propagation paths of electromagnetic waves using programmable materials, effectively addressing the poor penetration of high-frequency signals and enhancing signal coverage and transmission efficiency. Additionally, full-spectrum sharing technologies, such as AI-driven cognitive radio, will dynamically allocate and utilize spectrum resources, significantly improving spectrum utilization to meet the growing communication demands.

(2) Integrated network of air, space, ground, and sea

Future communication networks will no longer be limited to the ground but will build an integrated network covering air, space, ground, and sea. Low Earth Orbit (LEO) satellite internet, such as SpaceX's Starlink, OneWeb, and other LEO constellations, will provide seamless global coverage, ensuring reliable communication for remote areas and emergency situations.

High Altitude Platform Systems (HAPS), utilizing stratospheric drones or airships as temporary base stations, will effectively supplement network blind spots on the ground, enhancing the breadth and depth of network coverage. At the same time, underwater communication technologies based on blue-green lasers or sound waves will promote the development of the Internet of Underwater Things (IoUT), advancing the exploration and utilization of ocean resources.

(3) AI-driven smart communication networks

Optical communication technology is set to experience a new round of breakthroughs and innovations. Visible light communication (LiFi) technology will utilize LED light sources to achieve high-speed wireless communication, making it especially suitable for electromagnetically sensitive environments such as hospitals and airplanes. Silicon photonic integration technology will drive the development of low-cost, highly integrated optical chips, providing strong support for data center interconnections and 5G/6G fronthaul network upgrades. Hollow-core fiber technology, by reducing the interaction between light signals and materials, will effectively reduce latency and signal loss, improving the performance of optical communication systems.

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Future development trends

(4) Quantum Communication and Security

Optical communication technology is poised for a new round of breakthroughs and innovations. Visible light communication (LiFi) technology will leverage LED light sources to enable high-speed wireless communication, making it especially suitable for electromagnetically sensitive environments such as hospitals and airplanes. Silicon-based photonic integration technology will drive the development of low-cost, high-integration optical chips, providing strong support for data center interconnects and upgrades to 5G/6G fronthaul networks. Hollow-core fiber technology will effectively reduce latency and signal loss by minimizing the interaction between light signals and materials, thereby enhancing the performance of optical communication systems.

City Ranking

Rank	City/ Metropolitan Area	Rank	City/ Metropolitan Area
1	Beijing	11	London-Oxford-Cambridge
2	Shanghai	12	Paris
3	New York	13	Hangzhou
4	Boston	14	Hefei
5	Nanjing	15	Xi'an
6	San Francisco-San Jose	16	Seoul
7	Washington DC-Baltimore	17	Chicago
8	Guangdong-Hong Kong-Macao Greater Bay Area	18	Tianjin
9	Wuhan	19	Los Angeles
10	Tokyo-Yokohama	20	Shenzhen

In the 2024 global rankings for advanced communication cities, China holds 10 of the top 20 spots, including Beijing, Shanghai, and Shenzhen, reflecting its strength in communication tech. The U.S. has 6 cities, such as New York and San Francisco, demonstrating its leadership in innovation. Japan, South Korea, the U.K., and France each have one city (Tokyo, Seoul, London, Paris), showing their contributions to global networks.

Beijing and Shanghai are central to China's 5G and quantum communication breakthroughs, while U.S. cities lead in 5G infrastructure and next-gen networks like 6G. China's dominance is driven by strong investments and policy support, especially in 5G, while the U.S. leads through its research base and tech companies. These cities will continue to play a central role in global communications.

Enterprise ranking

Rank	Enterprise	Rank	Enterprise
1	HUAWEI	11	AT&T
2	Nokia	12	Verizon Communications
3	Ericsson	13	China Mobile
4	Qualcomm	14	Institute of Microelectronics, Chinese Academy of Sciences
5	Samsung Electronics	15	Skylink
6	SpaceX	16	Alibaba Group
7	ZTE Communications	17	Amazon Web Services (AWS)
8	Cisco Systems	18	IBM
9	Intel	19	MediaTek
10	Microsoft	20	T-Mobile US

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Biotechnology

Definition

Biotechnology is the application of fundamental principles from biology, chemistry, and engineering to utilize biological organisms (including microorganisms, animal cells, and plant cells) or their components (such as organelles and enzymes) to produce useful substances or provide services for humans. The core of biotechnology is genetic engineering, centered on recombinant DNA technology, and also includes fields such as microbial engineering, biochemical engineering, cell engineering, and bioproducts. As a rapidly developing field, biotechnology is having a profound impact on our lives, with breakthroughs in areas such as gene editing, synthetic biology, and biosensing technologies.

Summary of Outstanding Achievements in 2024

(1) Progress in Long-Acting HIV Therapy

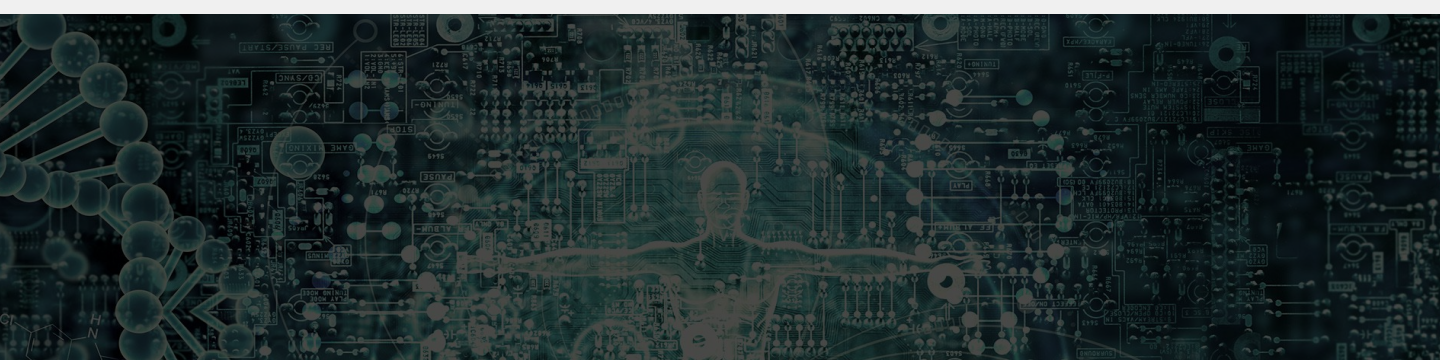
Researchers from Oregon Health & Science University and the University of California, San Francisco, have developed a synthetic therapeutic interference particle (TIP) that effectively suppresses the body's natural HIV virus by mimicking defective HIV. Non-human primate experiments have shown that a single TIP treatment can sustain suppression of HIV in the body for up to 30 weeks.

(2) Gene editing therapy approved

New-generation gene editing tools, such as CRISPR-Cas12 and CRISPR-Cas13, have shown significant improvements in precision and efficiency, reducing off-target effects and expanding applications in disease treatment and agriculture. In 2024, scientists successfully used CRISPR technology to cure various genetic disorders, such as sickle cell anemia and Duchenne muscular dystrophy. Furthermore, several CRISPR-based gene therapies have received FDA or EMA approval, marking the official entry of gene editing technology into clinical applications.

(3) AI Empowering Biotechnology

This year, the updated versions of AlphaFold and RoseTTAFold have once again captured global attention. These AI models not only predict the three-dimensional structure of proteins but also simulate interactions between proteins and DNA, RNA, and small molecules, offering new possibilities for drug design and protein function prediction. In the future, with the addition of more high-quality training data, the performance of these models will become even more accurate, potentially revolutionizing traditional drug development processes.



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Biotechnology

Future development trends

The future of biotechnology will focus on multiple areas, including precision medicine, gene editing, synthetic biology, and bioinformatics. With continuous breakthroughs in cutting-edge technologies such as gene editing, cell therapy, and protein engineering, personalized healthcare will become mainstream, providing precise treatment solutions for complex diseases like cancer and genetic disorders. Meanwhile, the deep integration of artificial intelligence and biotechnology will accelerate drug development and improve the accuracy and efficiency of disease diagnosis. In the field of regenerative medicine, stem cells and tissue engineering hold the potential to achieve organ regeneration, addressing the issue of organ shortages. Additionally, synthetic biology will drive the sustainable development of biomanufacturing and bioenergy, helping to tackle global environmental and resource challenges.

City Ranking

Rank	City/ Metropolitan Area	Rank	City/ Metropolitan Area
1	Boston	11	Shanghai
2	New York	12	Amsterdam
3	San Francisco-San Jose	13	Berlin
4	Beijing	14	Stockholm
5	Washington DC-Baltimore	15	Geneva
6	Singapore	16	Copenhagen
7	San Diego	17	Toronto-Burnaby
8	London-Oxford-Cambridge	18	Chicago
9	Tokyo-Yokohama	19	Wuhan
10	Munich-Stuttgart	20	Guangdong-Hong Kong-Macao Greater Bay Area

The top five cities in the biotechnology industry are Boston, Massachusetts; New York; San Francisco-San Jose; Beijing; and Baltimore-Washington. Among the top 20 cities, European cities occupy 7 spots, American cities hold 6, and Asian cities also account for 6. Overall, the United States is the global leader in the biotechnology industry, with the world's most successful biotech companies and the most advanced technologies. In Europe, the biotech industry is primarily concentrated in countries like Germany, the UK, the Netherlands, and Sweden; in Asia, it is mainly centered in China, Japan, and Singapore.

Enterprise ranking

Rank	Enterprise	Rank	Enterprise
1	Novo Nordisk	11	Chugai Pharmaceuticals
2	Thermo Fisher Scientific	12	Biogen
3	Amgen	13	AstraZeneca
4	Regeneron Pharmaceuticals	14	Merck KGaA
5	Novartis	15	Agilent Technologies
6	Vertex Pharmaceuticals	16	Seagen
7	Gilead Sciences	17	Illumina
8	Daiichi Sankyo	18	WuXi AppTec
9	Moderna	19	Samsung Biologics
10	Jiangsu Hengrui Medicine	20	Beigene

Conclusion

The Global Future Industry Index 2024 provides a comprehensive assessment of technological and industrial advancements shaping the future. It highlights the increasing dominance of the United States and China, with these two countries leading in various fields such as artificial intelligence, clean energy, and biotechnology.

The rankings reflect the global competitiveness of these nations, underscoring their investments in R&D, talent development, and emerging industries. Notable cities like San Francisco and Beijing are driving innovation, while countries in Europe and Asia, such as Switzerland and India, are making significant strides in sustainability, education, and industry diversification.

The year 2024 marks critical developments across various future industries, including quantum technology, clean energy, and humanoid robotics, where interdisciplinary integration is accelerating. Innovations in AI, gene editing, and brain-inspired technologies are also progressing, paving the way for future breakthroughs.

These industries are poised to revolutionize sectors ranging from healthcare and communications to energy and space exploration, contributing to global economic and social transformations. Moving forward, international collaboration and adaptability to trends will be essential in ensuring sustainable development and maintaining competitive advantage in the rapidly evolving technological landscape.

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