Opportunities and challenges for EU-China STI collaboration stemming from China's 14th Five-Year Plan

EU Research and Innovation Knowledge Network on China

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Preface

The EU-KNOC initiative was launched in July 2020, by the Directorate-General for Research and Innovation of the European Commission and the Strategic Forum for International Cooperation (SFIC) and is implemented by a consortium consisting of DLR Management Agency, Intrasoft, Teamwork, Technopolis and ZSI. EU-KNOC brings together representatives of the EU Member States' Ministries of Science, Technology and Innovation and other relevant ministries who constitute the Core China Group (CCG) and external experts to tackle thematic issues related to R&I policy towards China and to promote a common response.

As input and background information for the CCG of EU-KNOC, several studies are prepared by a research team. These studies aim to provide more in-depth knowledge regarding specific sub-topics within the wider area of STI collaboration with China.

The objective of this paper is to map **the opportunities and challenges for EU-China Science, Technology and Innovation (STI) collaboration**, as they emanate from China's 14th Five-Year Plan (FYP) (2021-2025) and related recent STI strategies. It fits into the broader EU goal to keep abreast of new developments in China's evolving STI strategy and practice, so as to ensure the development of **sustainable EU-China collaboration in STI** and contribute to **European STI excellence and resilience**.

Within this broad topic, the focus will be on those parts of the 14th FYP that offer opportunities for **scientific research and innovation collaboration**. A discussion of opportunities for corporate R&D, emanating from the 14th FYP's priorities for the manufacturing industry and core digital industries lies outside the scope of this paper. The paper is based on desk research of Chinese and English language sources and EU-KNOC CCG Recommendation Papers, complemented by interviews with five European S&T policy makers and experts on the preliminary findings of this paper.[1]

Due to the scope of this study, it does not address FYP on provincial-, municipal-, and sectoral level. For future studies, it would be interesting to look at examples of regional and sector-based FYP and how the central plan is implemented at the local level and in specific areas of STI.

[1] Frans Greidanus (Former Head of Research and CTO Asia for Philips); representatives of Datenna (China Economic Intelligence Company); Sylvia Schwaag-Serger (Lund University); Justyna Szczudlik (The Polish Institute of International Affairs); and Rebecca Arcesati (MERICS).

Content

1. China's 14th Five Year Plan and Vision 2035

1.1 Introduction

In March 2021, China's National People's Congress adopted the 'Outline of the 14th Five-Year Plan for National Economic and Social Development and Vision 2035 of the People's Republic of China (hereafter 14th FYP).[2] The document presents the country's **broad strategic blueprint for development** in the next five years as well as the country's mid- to long-term development goals for 2035. In developing FYPs, the Chinese government must consider the interests and conditions of a wide array of central level and regional stakeholders. Therefore, each FYP is carefully developed in a two-year process involving many national and international organizations and experts.[3]

Like its predecessors, the 14th FYP forms the basis for the development of numerous detailed policy plans in three categories:

- **Subnational**: FYP's fine-tuned to the situation at sub-national levels, including China's provinces, regions and cities;
- **Sectoral**: FYP's focusing on specific sectors, e.g. the '2021-2035 National Medium- and Long-term Science and Technology Development Plan', which is expected to be released later this year, or organizations, e.g. the FYP of the Chinese Academy of Sciences;
- **Theme focused**: FYPs and other plans focused on specific (sub)-themes, such as artificial intelligence (AI), or Basic Research, or the 'National Key Ecosystem Protection and Restoration Major Protects (2021-2035)'.

Although the Chinese government seeks to align all these plans, in practice this proliferation leads to a noodle bowl of sometimes competitive policies and initiatives, and to a less than efficient use, or even misuse, of funds.[4]

Although the 14th FYP presents various shifts in priorities and policies, it first and foremost reflects **continuity in China's STI policies**. It confirms and consolidates many elements of the strategies for technological innovation laid out in the 13th FYP, the 'Medium and Long-term Plan for the Development of Science and Technology (2006–2020)' and the 'Made in China 2025' plan.

Highlights of the 14th FYP and Vision 2035

STI is a central theme in the 14th FYP: the Chinese government clearly regards **advancing Science, Technology, and Innovation (STI) as the key** to China's overall development. The 14th FYP also presents an **ambitious STI roadmap**, aimed at two broad goals:

- Realizing **self-reliance in STI**
- Becoming a **global STI leader by 2035**.

Another **key aim** of the 14th FYP is achieving **quality growth** rather than quantity growth. This is reflected in the various major goals listed below but also in the fact that the 14th FYP does not include a specific GDP growth target, an 'historic first'[5] for a FYP. It states

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[2] National Development and Reform Commission (NDRC), 'Zhonghua renmin gongheguo guomin jingjihe shehui fazhan di shisi ge wu nian guihua he 2035 nian yuanjing mubiao gangyao [Outline of The Fourteenth Five-Year Plan for National Economic and Social Development of the People's Republic of China and the outline of the 2035 vision] March 2021. And 'Jīngjì xuu jia jiedu "shisiwu" guihua he 2035 nian yuanjing mubiao gangyao' [Economists interpret the "14th Five-Year Plan" and the outline of long-term goals for 2035], gov.cn, 14 March 2021. For an English translation see e.g. the website of the Center for Security and Emerging Technology.

[3] For more details, see Manfred Horvat, 'Understanding and Analysing China's Five-year Development Plan System, Parts 1, 2 and 3', EU-China Partnership Facility (ECPF), May 2021.

[4] Cao, Cong (27 December 2019). 'Progress and challenges for science and technology in China'. East Asia Forum.

[5] Global Times Staff Reporters (8 March 2021). 'China's 5-year plan to lead global recovery.' *Global Times.*

that instead yearly growth targets should be defined, in accordance with yearly circumstances. With this decision, the government acknowledges the many 'uncertainties for the Chinese economy, including severe global conditions and a shaky domestic recovery with constraints on consumption and investment'.[6]

Other **major goals** of the 14th FYP include:

- Implementing a (more) market-oriented approach to development
- Implementing China's new development paradigm: the Dual Circulation model[7]
- Achieving Common Prosperity[8]
- Developing innovative, high-end manufacturing sustained by secure, reliable high value added industrial and supply chains
- Strengthening the digitization of the economy
- Boosting green development
- Boosting China's domestic and global governance and the country's soft power

A second 'historic first' in the 14th FYP is the emphasis on 'security'. It contains a special section for the **development of security**, aimed at bolstering the national security system and capabilities, and setting arrangements to ensure food, energy and financial security in what China perceives as 'unstable and uncertain times'.[9] **Other priorities** of the 14th FYP that stand out in comparison to the two previous Five-Year Plans,[10] concern the areas of:

- **Culture, education, and ideology,** including the aim to 'strengthen the systematic research, publication, dissemination, publicity and interpretation of Xi Jinping Thought on Socialism with Chinese Characteristics for a New Era', and 'education on the history of the [Chinese Communist] Party' (CCP), 'patriotism, collectivism, and socialism' (see Chapter 34)
- **Opening up and international economy**, including promotion and strengthening of the Belt and Road Initiative, the economic integration of Asia within the Regional Comprehensive Economic Partnership (RCEP), and the linking of the Atlantic and the Pacific oceans through the Artic Road and the Central and Latin America networks.

Targets

The 14th FYP presents twenty indicators in areas relevant for achieving quality growth, covering the areas of economic development, innovation, people's livelihood and well-being, green development, and security/safety. Most of the twenty **targets are modest** and aligned with recent trends. Eight targets are binding, the remaining twelve are 'indicative' (see Box 1 of the 14th FYP in the Appendix). Most relevant for this study are two 'indicative' targets:

- **Growth in R&D spending** of more than 7% and 'a higher share in GDP than under the 13th FYP'.

[6] Global Times Staff Reporters (8 March 2021). 'China's 5-year plan to lead global recovery.' *Global Times.*
[7] The 'dual circulation' model seeks to increase the role of China's domestic circulation (the domestic market) in driving economic growth and innovation and reduce the country's dependency on external circulation or global integration. China's Minister of Commerce has emphasized that the dual circulation model does not mean that China will turn away from integration with the global economy. See Zhong Nan,'Openess to boost trade, FDI, spending'. *China Daily*, 9 March 2021
[8] Achieving 'Common Prosperity', meaning affluence shared by everyone in China, is the country's main objective for the next stage of its development.
[9] President Xi mentions this in many speeches, e.g. in an April 2021 speech at the Boao Forum.
[10] See the graphs in Nis Grünberg and Vincent Brussee, 'China's 14th Five-Year Plan – strengthening the domestic base to become a superpower', Merics, 9 April 2021; and see Horvat (2021).

In the period 2015-2020 China's R&D expenditure annually grew with 11.5%. China has not specified a *research intensity* goal for the 14th FYP period. The goal for the 13th FYP, 2.5% of GDP, was not realized. In 2020, R&D spending increased 10.3% to $378 billion, accounting for 2.4% of GDP.

- **Rise in the number of innovation patents** per 10,000 people: from 6.3 in 2020 to 12 in 2025.

Long-term goals

The **Vision 2035** sets out long-range development goals for 2035, when China is halfway its journey towards realizing the country's national rejuvenation in 2049. In 2049, China wants to be a 'strong, democratic, civilized, harmonious, and modern socialist country' and 'a global leader in national composite strength and international influence.'[11] **The objective for 2035** is: 'basically completing socialist modernization'. In more concrete terms the 2035 goals include:

- realizing a modernized (innovative) economy
- raising per capita GDP to the level of moderately developed countries being a **global leader in innovation** through achieving 'major breakthroughs in core technologies'
- achieving the **modernization of China's national defense and the military**
- achieving the modernization of China's system and capacity for governance.

1.2 STI priority areas in the 14th FYP

The 14th FYP highlights **science, technology, and innovation as drivers of China's development**. This priority is reflected in the order of topics addressed in the 14th FYP and in the order in which special scientific programs and projects are presented. The main STI-related goals and plans are dealt with in the four chapters of Part II of the 14th FYP ('Innovation-Driven Development to Build New Strengths'), after the introductory Part I. The special scientific programs and projects are also presented upfront, in Box 2: 'Tackling key scientific and technological frontiers'.

The 14th FYP considers a rapid strengthening of STI and **self-reliance in STI** as core prerequisites for achieving the overall goals of the 14th FYP and presents an **increased focus on investing in home-grown innovations and standards**. Increasing self-reliance has long been a goal of China's development plans but has recently gained importance as a result of the ongoing hi-tech war with the United States. The Chinese government realizes that the US is not only ahead in many areas of STI but also has leverage over China in the technology sector.[12]

Furthermore the 14th FYP clearly aims to **reform STI governance** and make China's STI system well regulated, more efficient, and greener. Some of the measures proposed to achieve these goals are discussed further below.

Scientific frontier areas

The 14th FYP presents a total of 119 key areas/projects divided over 19 main themes, presented in 19 boxes. The most relevant for this paper is box 2, which lists **seven**

[11] Xi Jinping (2017, October 18). 'Secure a Decisive Victory in Building a Moderately Prosperous Society in All Respects and Strive for the Great Success of Socialism with Chinese Characteristics for a New Era'. *Report to the 19th National Congress of the Communist Party of China*.
[12] Frank Tang, 'China puts supply chain security at forefront to avoid being 'strangled' by sanctions'. SCMP, 10 November 2020.

'scientific frontier areas' with their key (sub)areas/projects (see Table 1). These core technological areas have been identified as being essential to realize China's goal to become leading in STI and in high-end manufacturing, and therefore require **extra efforts and investments.**[13]

Table 1**:** Box 2 of the 14th FYP**: 'Scientific Frontier Areas' /Key core technologies**

Scientific frontier areas	**Projects/key areas**
1.New Generation Artificial Intelligence	*Breakthroughs in cutting-edge fundamental theories; AI Chip development; construction of open source algorithm platforms; innovations in deep learning reasoning and decision making, image graphics, speech and video, and natural language recognition processing.*
2. Quantum Communications	*Development of intra-city, intercity and free-space quantum communication technologies; general-purpose quantum computing prototypes and practical quantum simulators; Breakthroughs in quantum precision measurement technologies.*
3.Integrated Circuits	*Development/upgrading of key materials such as integrated circuit design tools, key equipment and high-purity targets; advanced integrated circuit processes and special processes such as insulated gate bipolar transistors (IGBTs) and micro-electro-mechanical systems (MEMS); advanced storage technologies; broadband semiconductors such as silicon carbide and gallium nitride.*
4. Brain Science and Brain-like Research	*Brain cognition analysis; brain mediated neural connectivity mapping; Research on major brain diseases and on development of child and adolescent brain intelligence; Development of brain-like computing and brain-computer fusion technology.*
5. Gene and Biotechnology	*Research and application of genomics, technological innovation in genetic cell and genetic breeding, synthetic biology and biopharmaceuticals; Development of innovative vaccines, in vitro diagnostics and antibody drugs, creation of new varieties of crops, livestock, aquatic animals and agricultural micro-organisms, and research on key biosafety technologies.*
6. Clinical Medicine and Health	*Basic research on cancer, cardiovascular, respiratory and metabolic diseases; Development of active health intervention technologies, regenerative medicine, microbiome and novel therapies; Research on key technologies for the prevention and treatment of major transmissible diseases and major chronic non-transmissible diseases.*
7. Deep space, deep ground, deep sea and polar exploration	*Basic research on the origin and evolution of the universe; Mars orbit, asteroid patrol and other interstellar exploration, a new generation of heavy launch vehicles and reusable space transportation system; deep-earth exploration equipment; deep-sea marine maintenance and equipment test ships; polar monitoring platform and heavy icebreakers; the 4th phase of the Lunar Exploration Project; the 2nd phase of the Jiaolong and Snow Xuelong explorations of the sea and the polar region.*

[13] 14th FYP, Chapter 4 'Strengthen National Strategic Science and Technology Forces'.

Investment in Basic Research

The 14th FYP highlights the need to strengthen **basic research**, which is described as 'the foundation for S&T development and the driving force of applied research'.[14] Basic research has long been considered one of the weaknesses in China's S&T landscape[15] and in order to improve it the Chinese government will:

- Formulate and implement a Ten-year Action Plan on Basic Research
- Raise the proportion of basic research funding to more than 8% of R&D funding
- Establish Basic Research Centers and support basic research at the Beijing Science and Technology Innovation Center
- Support the financing of basic research by tax incentives for corporate investment in basic research and society investment through donations and funds.

The central government's funding for basic research doubled over the past five years - in 2020 it was estimated at 6.2 percent of total R&D expenditure[16] - but this is far below the percentages of the EU (13 percent in the Horizon 2020 period) and the US (16.6 percent in 2018).[17] Furthermore, there is **no leap-frogging in basic research** as each step forward builds upon a full understanding of the previous steps; catching up will take time and needs an environment that nurtures creativity and independent thinking.[18] The latter is something that, also in the eyes of Chinese academics, is not well developed in China's academic system.[19]

Improving China's S&T Infrastructure

The 14th FYP states that China needs to 'fight a battle' for the key core technologies listed above (Table 1) and regards establishing **new national laboratories** and **reforming the existing state key laboratories** as a major way to improve China's S&T force. New national laboratories are to be established in fields like **quantum information, photonics and micro-nanoelectronics, network communications, artificial intelligence, biomedicine, and modern energy systems**. Furthermore, the Chinese government will optimize and upgrade innovation bases such as the National Engineering Research Centers and the National Technology Innovation Centers.[20] According to a 2020 Circular of China's Ministry of Science and Technology (MOST), the latter innovation centers will seek to convert science into technologies and **commercialize basic research**, tasks that are not yet well developed in China.[21]

The 14th FYP presents **four types of major national S&T infrastructures,** to be established in the period up to 2025:

- Strategically oriented networks, systems, and facilities[22]
- Application-supported facilities [23]

[14] 14th FYP, Chapter 4.
[15] Liu, Yin and Cao, Xiuying (1 March 2021), *Science & Technology Daily*; and Kennedy, A. (2019). China's Rise as a Science Power. *Asian Survey, 59*(6), 1022-1043.
[16] Xinhua (8 March 2021). 'China to boost support for basic research over next five years: minister'.
[17] https://fas.org/sgp/crs/misc/R44307.pdf
[18] Interview for this project.
[19] Qian Y. (2020). 'Qian Yingyi: What's Missing in Chinese Education? Creativity'. *Caixin*, 5 August 2020.
[20] 14th FYP, Chapter 4.
[21] HKTDC (April 2020), 'China Promotes Development of National Technology Innovation Centres'.
[22] Such as 'a ground-based monitoring network for the space environment, high-precision ground-based timing system, large-scale low-speed wind tunnel, scientific observation network for the seabed, ground-based simulation device for the space environment, and comprehensive research facility for the key systems of the fusion reactor mainframe'.
[23] Such as 'a high-energy synchrotron light source, high-efficiency low-carbon gas turbine test facility, hypergravity centrifugal simulation and test facility, accelerator-driven transmutation research facility and future network test facility'.

- Forward-looking and leading devices and facilities[24]
- Facilities and laboratories aimed at improving people's livelihood.[25]

'Establishing' in this context does not always mean building an entire new facility; in many cases existing facilities are brought together and/or are expanded and upgraded and given a new name.

The STI infrastructure plans will be elaborated in more detail in the **Medium and Long-term Plan for the Development of Science and Technology (2021–2035)** (hereafter MLP 2021-2035), which is expected be published later this year. The proposals of the MLP 2021-2035 indicate that the plan will largely build upon the fifteen mega science and mega-engineering programs that were presented in the previous MLP 2006-2020, and the 13th FYP. Mega programs that have already been launched are in the areas of **quantum communication and quantum computing; brain science and brain-inspired intelligence;** and include **a deep-sea space station** and an **integrated space–earth information network.** So far, these costly MLP 2006-2020 's mega-engineering programs have generated **mixed outcomes**.[26]

The Chinese government also promises stronger support for research institutes and laboratories working on strategic technologies and cutting-edge science in specific regions and locations. The 14th FYP promotes the formation of:

- **International STI centers** in Beijing, Shanghai and the Guangdong-Hong Kong-Macao Greater Bay Area
- **Comprehensive national technology innovation centers** in the Beijing-Tianjin-Hebei Region, the Yangtze River Delta, and the Guangdong-Hong Kong-Macao Greater Bay Area
- **Comprehensive national science centers** in Beijing Huairou, Shanghai Zhangjiang, Greater Bay Area, Hefei, and Anhui.[27]

China previously aimed for 700 'key state laboratories' for fundamental research to be established by the end of 2020. According to Chinese sources there are currently 529 State Key Labs in China, including in Hong Kong and Macao. They are supported and funded by the central government and are run by universities (the majority), research institutes, enterprises, ministries, and military units.[28]

In addition, the 14th FYP calls for the improvement of the level and efficiency of **resource sharing**, between scientific research institutes, universities and enterprises, e.g. through:

- building a natural science and technology resource bank
- national field scientific observation and research stations (network), and a
- scientific big data center.

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[24] Such as 'a hard X-ray free electron laser device, high-sea cosmic ray observatory, comprehensive extreme conditions experiment devices, deep underground very-low radiation background frontier physics experiment facility, precision gravity measurement research facility, strong current heavy ion accelerator device'.

[25] Such as 'translational medicine research facility, multimodal cross-scale biomedical imaging facility, model animal phenotype and genetic research facilities, seismic science laboratory, and earth system numerical simulators.'

[26] Cao, Cong (27 December 2019). 'Progress and challenges for science and technology in China'. East Asia Forum. See also European Commission (2017), [China's] 'National S&T Megaprojects'.

[27] Speech by Minister of S&T, Wang Zhigang, CCTV, 2 January 2021. Since 2105, MOST has approved the establishment of six new national research centres, specializing in molecular sciences (Beijing), opto-electronics (Wuhan), condensed matter physics (Beijing), information S&T (Beijing), materials science (Shenyang) and microscale materials science (Hefei), see Cao, Cong (2021) 'UNESCO Science Report', Chapter 23 'China', pp. 623-640.

[28] Li, Peijuan (16 June 2021). 'Analysis of China's State Key Laboratory Market Status and Development Trends in 2021'. *Qianzhan.*(in Chinese)

Expanding and strengthening human resources

China has a large pool of scientists and academic talents. Each year millions of students graduate from Chinese universities – in 2021 over 9 million[29] – and China is home to a large share of global researchers: in 2018 China accounted for 21.1 percent of global researchers, just below the EU's share of 23.5 percent.[30] Nevertheless, the country lacks human resources to achieve its goals, in particular, high-level human resources in STI.[31] In order to make a career in science more attractive, the 14th FYP seeks to provide more incentives to scientists through:

- Providing selected top talents with authority to decide on technical routes and the use of funds
- Exploring the possibility of granting scientific researchers the ownership or long-term rights to use their scientific results
- Increasing the proportion of revenue sharing among scientific researchers
- Implementing a compensation policy oriented towards increasing the value of knowledge
- Improving the mechanism for evaluating science and technology, and awarding scientists.

The first two incentives show that the Chinese government acknowledges the weaknesses that arise from top level designed STI plans. However, they will be difficult to realize against the background of the current strengthening of CCP and government leadership over education and S&T. The last incentive has already been elaborated upon in the last two years in a set of policies aimed at reforming China's research evaluation and peer review systems, and improving research ethics.[32] They address:

- The evaluation of S&T projects and programs
- The evaluation and promotion of individual scientists
- China's academic publishing system
- Breaches of academic integrity resulting from the pressure to publish in top international journals.

New regulations address, for example, the 'international citation worship' among Chinese researchers, which is seen to come at the expense of attention to the quality and economic and societal value of research.[33] A major element of the reform concerns steps to reduce reliance on indicators based on international Web of Science publications (previously Science Citation Index) and instead include evaluation of different types of scientific research work. A new requirement, for example, is that one third of all scientific articles used to evaluate a person's research are published in domestic Chinese journals.[34] These developments may have consequences for the international visibility and international assessment of Chinese researchers. Furthermore, as international competition is an

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[29] Xinhua (13 May 2021). 'China will have 9 mln new college graduates this year.

[30] The USA accounted for 16.2% (2017).
UNESCO (2021). 'UNESCO Science Report: The race against time for smarter development, p. 51.

[31] Wang Zhigang (16 March 2021), 'Commit to self-reliance and accelerate the building of a science and technology powerhouse'. *Qiushi* [Seeking Truth].

[32] The most recent is a publication by China's State Council on 2 August 2021 entitled the Guiding Opinions on Improving the Evaluation Mechanism of Scientific and Technological Achievement. See also Xinhua (28 July 2021), interview with Minister of MOST. However, the start of a broader process of S&T project evaluation lies further back; see e.g. the 'Notice on the Plan for Deepening the Reform of the Management of Centrally-Financed S&T Projects (Programmes, Funds), Guo Fa [2014] No. 64'.

[33] See e.g. Qiang Zha (17 July 2021).'Why is China falling behind on breakthrough innovation?' *University World News*. Zhang and Sivertsen (2020), Zhang, L. and Sivertsen, G. (2020, June 11). 'For China's ambitious research reforms to be successful, they will need to be supported by new research assessment'. *London School of Economics*. Tao (11 May 2020).

[34] Xinhua (24 February 2020). 'China moves to change paper-reliant academic evaluation system in universities. Ministry of Education.

important driver in S&T, the new evaluation system may not necessarily result in a higher quality of scientific work.

In addition to the above, China also seeks to cultivate more innovative talents by **strengthening the country's educational foundation**. The 14th FYP aims to rise the average years of education of the working-age population from 10.8 in 2020 to 11.3 in 2025, one of the few binding targets in the document.[35] Furthermore, in June 2021, China's State Council issued the **National Action Plan for Scientific Literacy 2021-2035**, which seeks to improve the population's scientific literacy from the current 8 percent to 15 percent by 2025, and 25 percent by 2035.[36]

Improving the funding of STI[37]

The 14th FYP aims to strengthen innovation capabilities in scientific research through higher investment in corporate R&D, and better collaboration between scientific research institutes, universities and enterprises in allocation and sharing of financial resources. In 2018, 76.6 percent of R&D in China was funded by business, compared to 20.2 percent by the government. Only 0.4 percent of funding came from abroad (see table 4 on p 13). The new plans will likely build upon previous plans to reform financial management of S&T programs, which focused on integrating research plans from different governmental departments in order to use resources more efficiently.[38] China also plans to reserve a greater role for experts instead of administrators in deciding upon and managing funding programs, and to make grant application less burdensome for scientists. In addition, Chinese scientists will be able to earn more bonuses under the new system.[39]

1.3 International collaboration

The 14th FYP seeks to strengthen China's international S&T cooperation strategy and to **integrate China more proactively into global innovation networks.** As expressed in various policies and speeches in recent years, China hopes to accelerate the **internationalization of high-level research** in the country, or in other words, to have more international scientists involved in high-level research taking place in China. Although talent plans are less prominent in the 14th FYP compared to its predecessor, the 14th FYP does call for attracting and cultivating domestic and foreign talents. It promises to:

- Implement a more open, inclusive, mutually beneficial, and shared international strategy for cooperation in S&T
- Step up efforts to open up national S&T programs to the outside world
- Launch major science and technology cooperation projects
- Study the possibilities for establishing a global scientific research fund
- Implement scientist exchange programs
- Support the establishment of international scientific and technological organizations in China
- Appoint foreign scientists to scientific and technological academic organizations in China
- Promote international cooperation in the fields of global epidemic prevention and control and public health, and boost joint research on climate change

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[35] Other binding targets are in the area of ecology (5) and security/safety (Comprehensive grain production capacity and comprehensive energy production capacity. See box 1, 'Main indicators of economic and social development during the "14th five-year plan" period', on p. 10 of the FYP (Chinese version).
[36] Zhang, Zhihao (7 July 2021). 'Scientific literacy plan announced. *China Daily*.
[37] For more information about STI funding see e.g. EC (2018) 'Advance EU Access to Financial Incentives for Innovation in China. Guide for EU stakeholders on Chinese national STI funding programmes'. EC (2018) FWC FPI/PSF/2015 Lot 4.
[38] STINT (2020). 'Public Research and Innovation Funding Actors in China'.
[39] Zheng, William (29 July 2021) China to cut red tape for scientists applying for research funding. *SCMP*.

- Take the lead in designing and initiating international big science programs and projects.

In a recent speech,[40] Minister of Science and Technology (MOST), Wang Zhigang, added plans to:

- Build an international talent system and develop an internationally competitive talent training and introduction system
- Build multilateral science and technology cooperation mechanisms
- Accelerate the launch of China-led international major scientific programs
    - China has participated in various international mega projects and argues it is now ready to also lead some of these endeavors. In 2018 Chinese scientists put the long-running Meridian Project, a space-monitoring initiative, forward as a candidate.[41]
- Implement The Belt and Road Science and Technology Innovation Action Plan[42]
- Deepen STI cooperation between the Mainland and Hong Kong and Macao
- Accelerate the construction of international STI centers with international competitiveness in Beijing, Shanghai, and the Guangdong-Hong Kong-Macao Greater Bay Area.

Many of these plans concern ongoing efforts; more concrete details may be provided in the upcoming MLP 2021-2035 and other sectoral plans.

In addition to recruiting high-level talents that are trained abroad, the Chinese government now also seeks to **foster foreign 'globally competitive, high-calibre professionals' trained in China**, e.g. through the establishment of international research centers in China. To make China a more internationally competitive and attractive environment for overseas high-end talents and professional scientists to work in, the 14th FYP aims to improve the system of granting permanent residence for foreigners in China, as well as the system of their remuneration and benefits, children's education, social security and tax concessions. In addition, it aims to enhance exchanges at the base level through improving international courses and programs at Chinese universities.[43] In the summer of 2019 China's Ministry of Public Security announced a relaxation of immigration rules for obtaining long-term visas and permanent residence permits with the aim of facilitating the influx of highly skilled foreign researchers and workers.[44] However, due to China's 'zero tolerance' Covid-19 policy and travel restrictions, China's inbound (student and) scientist exchanges have almost come to a standstill. Outbound mobility of Chinese students and scholars to countries with less strict entrance rules seems to pick up again for the academic year 2021-2022.[45]

[40] Wang, Zhigang (16 March 2021), 'Commit to self-reliance and accelerate the building of a science and technology powerhouse'. *Qiushi [Seeking Truth]*
[41] Ji, Jing (17 May 2018). 'Taking on Mega Science'. *Beijing Review.*
[42] This Plan aims to strengthen S&T collaboration with countries that have joined China's Belt and Road Initiative. For more details see d'Hooghe Ingrid (2021). China's BRI and International Collaboration in Higher Education and Research. A symbiotic Relationship', in Schneider, F. (Ed). *Global Perspectives on the Belt and Road Initiative*. (Amsterdam University Press).
[43] Ministry of Education (MoE) (2020, June 22). 'Ministry of Education publishes plans on further opening of education'.
[44] Zhuang Pinghui (17 July 2019). 'China relaxes immigration rules to attract and retain more highly skilled overseas talents', *SCMP*.
[45] See e.g. figures of the UK and The Netherlands.

Overview of China's STI Landscape in figures[46]

Table 1: **R&D expenditure** (2019), in billion US$

China	EU 27	US
514.8	390.05	612.7

Table 2: **R&D intensity** (R&D spending in percentage of GDP) (2019)

China	EU 27	US
2.2	2.1	3

Table 3: **Type of research** (2018), in percentages

Type of research	China	EU27
Experimental research	83.3 (2018)	
Applied research	11.2 (2018)	
Basic research	5.5 (2018) (2019: 6%)	13 (under Horizon 2020 Programme)

Table 4: **Source of R&D funding** (2018) in percentages

Source of funding	China	EU27
Business	76.6	58.6
Government	20.2	30
Abroad	0.4	9.2

Research output and impact

In 2019, China became the **world's second largest producer of scientific papers**. While papers from the US and Europe on average still have the most impact and are more highly cited, the number of high impact Chinese papers is rapidly increasing.[47] According to a recent policy brief by the European Commission, **China has overtaken the EU** in terms of shares of both the top 10 percent and the top 1 percent most highly cited scientific publications in 2015 and 2016 respectively.[48]

Table 5**: *Scientific publications by field of science,*** *in percentages*[49]

Cross cutting strategic technologies	24
Health Sciences	19
Engineering	15
Physics and Astronomy	11
Chemistry	10
ICT, Math, Statistics	9

Universities and research institutes

According to the Nature Index 2020, the world's top research institution is The Chinese Academy of Sciences, ranking first in the areas of chemistry, earth and environmental sciences, and physical sciences.[50] In the 2020 CWTS Leiden Ranking of universities, which looks at scientific performance based on bibliometric data, Chinese universities outnumbered US universities for the first time.[51]

[46] Sources for tables 1-4: OECD (2021). 'Main Science and Technology Indicators' (performance in 2019) and 'MSTI highlights on R&D expenditure, March 2021 release', https://www.oecd.org/sti/msti-highlights-march-2021.pdf; and Cao, Cong (2021), 'UNESCO Science Report', Chapter 23 'China', pp. 623-640.
[47] NSB 2020 & CWTS 2020.
[48] Joint Research Council of the European Commission (2021). 'China overtakes the EU in high impact publications', Science for Policy Briefs.
[49] UNESCO Science Report, p. 630.
[50] Nature (2020). 'Nature Index 2020', https://www.natureindex.com/annual-tables/2020/institution/all/all
[51] Times Higher Education (2020). 'World University Rankings 2021'. Centre for Science and Technology Studies (CWTS) (2020).'The 2020 CWTS Leiden Ranking'.

1.4 Weaknesses and strengths of China's STI policies

Chinese STI plans, including the 14th FYP, are often comprehensive and formulated in broad and general terms. As an overall blueprint for national development, it does not dwell upon details. However, even the more detailed plans usually lack specifics, on funding as well as on how new projects relate to existing projects.

Noodle bowl of plans and projects

The Chinese government and other STI stakeholders publish a plethora of STI plans in China, many of which overlap. The status of the projects and initiatives that are presented in the national 14th FYP and in the many subnational and theme focused FYPs, is often unclear: some projects are already being implemented (e.g. the new STI evaluation mechanisms) while others may only reflect an unspecified vision for the future; some FYP key projects may be implemented through reforming existing projects, – and renaming them – while others may need to be build up from the ground. Furthermore, some STI projects are implemented without being publicly announced, especially military-oriented projects,[52] and other projects are announced but never realized. In addition, different plans and speeches may use slightly different names or descriptions when referring to initiatives and facilities. Together, these features provide observers in China and abroad with obstacles to getting a full and accurate overview of the country's STI system.

Weaknesses in China's STI system

In addition to supporting the country's STI ambitions, the 14th FYP also focuses on addressing specific **weaknesses in China's current STI system**. In speeches in February and March 2021, Minister of Science and Technology, Wang Zhigang, said that despite enormous investments in STI and the country's many achievements, China's STI still suffers from serious shortcomings:[53]

- Lack of autonomy in core technologies
- Weak basic research
- Insufficient supporting capacity for industrial supply chains
- Inefficient innovation system
- Lack of top talents and high-level teams.

In March 2021, the theoretical journal of the CCP, *Seeking Truth* (Qiushi), published a 2018 speech by President Xi Jinping, in which he mentions the same shortcomings.[54]

As discussed in the previous paragraphs, China's STI policies seek to address each of these shortcomings with specific plans and actions. However, the question arises if the fundamental characteristics of China's STI system are conducive to realizing the country's STI goals. The Chinese STI system is primarily **state designed and state led** and the country adheres to a '**whole of the nation' system in STI**, which is based on the government's commitment to mobilizing national resources for priority areas in the

[52] See e.g. Bitzinger, R., & Raska, M. (2015). The Chinese People's Liberation Army in 2025 (pp. 129-162, Rep.) (Kamphausen R. & Lai D., Eds.). Strategic Studies Institute, US Army War College. These classified projects reportedly include the Shenguang Laser Project; the Second Generation BeiDou Satellite Navigation System; and the Hypersonic Vehicle Technology Project.

[53] SCIO (26 February 2021) 'SCIO on making China a country of innovators'; and Wang Zhigang (16 March 2021), 'Commit to self-reliance and accelerate the building of a science and technology powerhouse'. *Qiushi* [Seeking Truth].

[54] Xi Jinping (2021). 'Strive to Become the World's Primary Center for Science and High Ground for Innovation'. *Qiushi* [Seeking Truth].

development of STI.[55] The 14th FYP also emphasizes that STI approaches should consider not only societal but also political and ideological interests, including those of the Chinese Communist Party (CCP) and Xi Jinping Thought.[56] This dominant role of the state and the CCP leads to many **challenges and problems**, including:

- Failures in linking S&T to the economy, e.g. commercialization of (basic) research and the translation of scientific results into innovation capacity
- Obstacles to shifting innovation leadership from the state to businesses and from policy makers to entrepreneurs[57]
- Inefficient allocation of resources, e.g. overinvestment in prioritized areas)
- Weakness in basic research.

Furthermore, several **policy tensions** emanate from the 14th FYP, which will be difficult to reconcile for policy makers. There are tensions between:

- The aim for self-reliance ←→ and the aim to accelerate the internationalization of STI. Balancing between these aims may lead China to strengthen its already strategically focused approach towards international STI-collaboration, seeking more ardently joint projects that fill specific gaps in Chinese knowledge and/or address China's strategic needs in STI development, including the need for (international) high-level talents.
- The aim to increase the role of business in STI and expose research to market dynamics ←→ and China's adherence to a state-led design and state-led implementation of STI policies. In recent years the role of the state and of state-owned enterprises in China's economy has been enlarged whereas the private sector has had to deal with nationalizations, business restrictions, financial reforms, and political uncertainties.[58] These uncertainties are not conducive to building trust between business and research organizations and form an obstacle for the strengthening of collaboration between the two sectors.
- The aim to give more room to scientists to take the lead in designing and developing STI projects and to stimulate creativity ←→ and the strengthening of both political oversight and the role of the CCP ideology in all endeavors, including in STI. This tension hampers the development of an open and creative scientific climate.

Strengths of China's STI system

China's STI system and approaches also have strengths, which have led to the country's remarkable success in developing STI. They include:[59]

- Strong investments in STI
- A strategic long-term view on STI and the formulation of clear and ambitious targets

[55] Sun, Yutao and Cao, Cong (8 May 2021) 'China's plan to become a world-leading technology force'. East Asia Forum; and, Cao, Cong (27 December 2019). 'Progress and challenges for science and technology in China'. East Asia Forum.
[56] Throughout the 14th FYP, see e.g. Chapter 34 of the 14th FYP.
[57] Some weaknesses are acknowledged by Chinese policy-makers, see e.g. the 14th FYP which aims to strengthen the connection between STI and the economy, and Wang, Zhigang, in SCIO (26 February 2021) 'SCIO on making China a country of innovators; other weaknesses are pointed out in e.g. Cao, Cong (27 December 2019). 'Progress and challenges for science and technology in China'. East Asia Forum; Suttmeier, Richard P. and Cao, Cong (2017), 'Challenges of S&T system reform in China.' *Science.*
[58] See e.g. Livingston, Scott (October 2020). 'The Chinese Communist Party Targets the Private Sector'. CSIS; Shunsuke Tabeta (17 January 2020). 'Deal breaker? China nationalizes strategic tech with eye on US.' *Nikkei Asia*; and Brueghel Institute (9 June 2021). 'Challenges and growth of China's private sector'. Podcast, Garcia-Herrero, Alicia, from minute 23 onwards.
[59] As observed by participants with much experience in STI collaboration at the 5th EU-KNOC Expert Meeting on R&I value chain dependencies on China, 27 May 2021.

- A 'whole of nation' system, which allows for a pooling of national resources to achieve a specific goal
- An ability to move fast
- A willingness to follow a trial-and-error strategy
- A commitment to setting the development of standards up front
- A focus on developing multi-disciplinary approaches and building multi-disciplinary labs.

In comparison to China, major EU weaknesses are considered to include moving slower and being more reactive than China. EU strengths are believed to lie in the EU's history and track record of strong industry and science contributions, and the capacity of organizing and orchestrating global networks.[60]

2. Caveats and Opportunities for STI collaboration

China is making big strides in STI. As a result of strategic policies and strong financial investments in STI, the country is rapidly strengthening the quality and quantity of scientific research, developing new technologies, and improving its innovation capacity. The 14th FYP presents strong ambitions for further improving China's STI and proposes many strategic policies towards achieving these ambitions. This makes China an important international partner in STI. Indeed, for the EU and many EU MS, **collaboration with China in STI is indispensable,** for both tackling global challenges and maintaining the EU's STI competitiveness. However, China's development in STI and its STI policies and practices also pose challenges to the EU and EU MS. Therefore, in its **Communication on the Global Approach to Research and Innovation** of May 2021, the European Commission calls for a rebalancing of research and innovation cooperation with China.[61] Before looking into the opportunities for STI collaboration that emanate from the 14th FYP, the various caveats of collaboration with China need to be discussed.

2.1 Caveats of collaboration

The European Commission (EC) and many stakeholders in EU MS have concerns about STI collaboration with China. They consider the current STI-relationship unbalanced and note that China does not always play to EU rules aimed at fostering a fair and non-distortive innovation ecosystem, defined by reciprocity, a level-playing field, and the respect for high ethical and science integrity standards.[62] Furthermore, they are concerned that collaboration may raise issues related to the safeguarding of strategic assets, interests, autonomy, or security. The risks and challenges of EU-China STI collaboration have been extensively discussed in recent years[63] and will only be briefly recapped below.

Lack of reciprocity[64]

The lack of reciprocity in STI collaboration pertains to issues such as access to research information, data and facilities, freedom of research, opportunities in international funding

[60] 5th EU-KNOC Expert Meeting on R&I value chain dependencies on China, 27 May 2021
[61] European Commission (2021). 'Communication on the Global Approach to Research and Innovation'
[62] In addition to the EC communication mentioned in the previous note see also Kelley, Eanna (15 February 2021). 'Talks on future science partnership with China 'not an easy exercise'. *ScienceBusiness.*
[63] See e.g. Asia-Pacific Research and Advice Network (ed.) (2019): Chinese Foreign Influence and Interference in Europe: Academia. (APRAN Study, No. 11); D'Hooghe, I., et al. (2018). 'Assessing Europe-China Collaboration in Higher Education and Research'. D'Hooghe, I. and Lammertink, J. (October 2020). Towards Sustainable Europe-China Collaboration in Higher Education and Research. LeidenAsiaCentre.
[64] Reciprocity is defined as: lack of equal treatment and equal opportunities in research afforded to EU researchers and other STI stakeholders working in or with China compared to the treatment offered to Chinese researchers and STI stakeholders working in or with the EU.

programs and actual funding, IPR protection, research ethics, openness and transparency, contract compliance, and equal conditions for mobility (e.g. visas).[65] China is addressing issues regarding IPR and research ethics, which may result in more reciprocity in these areas. However, **strategic barriers to reciprocity** linked to China's strategic interests as presented in the 14th FYP – e.g. the goal to attain self-reliance and global leadership in STI – will likely become **more prominent**. A potential consequence is more Chinese government restrictions on sharing or exporting (joint) research that the Chinese side labels as being 'strategic' (see also the paragraph on legislation below).

Dual use policies and civil military integration

In China, all STI policies serve the country's national development, national security, and rejuvenation strategies and policies. The 14th FYP explicitly mentions the strengthening and modernization of national defense and the armed forces (see e.g. Part XVI of the 14th FYP). These policies are underpinned by **military-civil integration in STI**, which refers to the interlinking of military and civilian S&T resources and the coordination of research and innovation with the aims of advancing both economic and military development and the development of advanced dual-use technologies.[66] Dual-use policies include the sponsoring of Chinese military researchers to study at universities around the globe,[67] and recruitment by the Chinese military and defense organizations of graduates and scholars of civilian HE&R institutions for conducting scientific research in areas relevant to the military.[68]

Many technologies that are part of EU-China STI collaboration can be used in both civilian and military applications, touching upon aspects of competitiveness and innovative capacity, market access, human rights, and national security concerns. **Vulnerable areas for dual-use application** include AI, ICT, biotechnology, quantum physics, avionics and aerospace, robotics and naval technologies.[69] As one expert in EU-China STI collaboration remarked: 'even though a topic may seem to fully service scientific interests, there are often possibilities for applications for military purposes and researchers are often not sufficiently aware of this: an example is gravitational-wave, in which Chinese military has already an interest for technological application.'[70]

Interference by China

STI interference by China may include actions aimed at undermining values and research integrity and unwanted and/or unlawful knowledge and technology retrieval through political or economic pressure, financial incentives, security breaches, or spreading disinformation. Interference activities can be targeted at STI organizations such as universities as well as individual researchers. Examples range from espionage and hacking to intimidation of Chinese scholars abroad and Chinese government sanctions against

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[65] For an extensive list see 'EU-KNOC CCG Recommendation paper #3, Table 3, pp. 24-30. For examples of lack of reciprocity in EU-China collaboration see e.g. Wallace, N. (2020, April 6). 'Access to information an obstacle in EU-China joint research'. *Science Business;* and D'Hooghe, I., et al. (2018).
[66] See e.g. Kania, E. and Wood, P. (2020). 'The PLA and foreign technology'. In Hannas, W.C. and Tatlow, D.K. (2020). *China's Quest for Technology. Beyond Espionage.* Routledge. 226-236; and Nouwens, Meia and Legarda, Helena (2018). 'China's pursuit of advanced dual-use technologies' IISS and Merics.
[67] Joske, Alex (2018). 'Picking flowers, making honey. The Chinese military's collaboration with foreign universities'. *ASPI Policy Brief*, Report No. 10/2018. See also Joske, A. (2019). 'Recommendations for Universities' and 'Recommendations for the Australian Government'. In the China Defence Universities Tracker: Exploring the military and security links of China's universities. *Australian Strategic Policy Institute.*
[68] Tay, K. (2020, May 7). 'China's military looks to civilians to boost innovation'. *IISS.* Retrieved 1 October 2020.
[69] For a more comprehensive list of vulnerable technologies see European Commission (2020. 'EU Dual Use Research guidance-draft version for Targeted Consultation'.
[70] 5th EU-KNOC Expert Meeting on R&I value chain dependencies on China, 27 May 2021.

individual European researchers and think tanks.[71] The European Commission's forthcoming guidelines on 'Tackling R&I Foreign Interference'[72] may support research organizations in developing sustainable international collaboration with China.

Impact of recent Chinese legislation on STI collaboration

Data protection laws and regulations

In recent years China has introduced various new laws and regulations that govern cybersecurity, data security and data protection, including the collection, use, storage, management and sharing of data in China and within international STI cooperation between foreign and Chinese entities. They include: the Data Security Law,[73] the Cybersecurity Law[74], the Personal Information Protection Law (PIPL, which comes into effect on 1 November 2021)[75], and the Measures for the Management of Scientific Data.[76] In 2020 China also introduced the Export Control Law,[77] which provides for export control of goods, technologies, data, services, and items that relate to protecting national security interests and fulfilling international obligations relating to non-proliferation. These laws **affect STI cooperation with China** in many ways, e.g. by restricting the sharing and export of joint research results, or obligations to store research data in China. This means that it is **necessary to perform extensive due diligence**, including **a careful compliance check** with these laws and regulations before entering into a joint project with Chinese counterparts. For more details see the **EU-KNOC paper 'China's specific regulatory framework on data and how it impacts EU-China R&I collaboration**' of September 2021.

Anti-Foreign Sanctions Law

The Anti-Foreign Sanctions Law (AFSL),[78] which took effect in June 2021, may also seriously affect European STI collaboration with China. The law provides a legal basis for the Chinese government to take countersanctions against a foreign country, organization, or individual directly or indirectly involved in measures or sanctions that contain or restrict Chinese citizens or organizations or interfere in China's internal affairs. It also allows for Chinese measures against individuals and organizations for conduct that endangers China's sovereignty, security, or development interest (art. 15), a formulation that offers possibilities to take measures against 'a wide range of actors and actions including documenting, criticizing, or advocating against China's policies and narratives'.[79] The countermeasures may include denial of visas and entry into China, and expulsion from China; seizure or freezing of assets located in China; and prohibition or restriction of Chinese individuals and organizations from cooperation with these foreign entities. An example of how such countermeasures may affect STI collaboration are China's sanctions against individual European China scholars and think tank MERICS of March 2021.

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[71] See e.g. Hannas, W.C. and Tatlow, D.K. (2020). *China's Quest for Technology. Beyond Espionage.* Routledge. For the Chinese sanctions against MERICS and individual China scholars see this announcement of China's Ministry of Foreign Affairs, (22 March 2021).
[72] European Commission, EU Guidelines on Tackling R&I Foreign Interference (forthcoming).
[73] The Chinese version of the DSL, National People's Congress; unofficial translation of the DSL.
[74] Chinese version CSL, Cyberspace Administration of China; unofficial English translation CSL.
[75] The Chinese version of the PIPL, published by the National People's Congress.
[76] Chinese version of the MSSD, published by the State Council; unofficial English translation of the MSSD.
[77] Chinese version of the ECL, published by the State Council; unofficial English translation of the ECL.
[78] Chinese version of AFSL, published by the NPC; unofficial English translation of the AFSL.
[79] Legarda, Helena, and Drinhausen, Katja (24 June 2021). 'China's Anti-Foreign Sanctions Law: A warning to the world'.

2.2. Opportunities for STI collaboration

This paragraph discusses general opportunities for sustainable scientific research collaboration with China emanating from the 14th FYP and related documents. It refers also to potential areas for collaboration identified in EU documents.[80] It focuses on the seven 'frontier sciences' highlighted in the 14th FYP (see Table 1 above) and on green development, which also figures prominently in the 14th FYP. Furthermore, it indicates caveats of collaboration in specific fields and draws attention to China's investment in developing multidisciplinary approaches and labs.

In view of the broad scope of each of these eight research areas, this study provides only **a general and limited overview** of the state of play in China and the opportunities for EU-China collaboration these areas offer. Therefore, **further elaboration on these topics by experts on each of the specific research areas is necessary and highly recommended,** also in view of the legislation discussed above.

1. New generation artificial intelligence

The field of AI tops the list of the 'frontier sciences'. This is no surprise. Already in 2017, with the launch of the Next Generation Artificial Intelligence Development Plan, the Chinese government singled out AI as an area that would serve new industries, contribute to national security, and that would give China an important competitive advantage. The plan laid out the aims for China to catch up with leading AI technology and applications by 2020 and become a global leader in AI technology and a leading force in defining ethical norms and standards for AI in 2030.[81] China is indeed rapidly advancing in this field. In 2019, AI was the fastest expanding discipline at Chinese universities, with 188 new undergraduate programs.[82] China is also successful in producing AI patents and research papers; has advantages in access to data and market dynamics that feed into AI research through close collaboration on data collection and analysis between the Chinese government and national AI champions such as Baidu, Alibaba and Tencent;[83] and has an edge over the US on the application of AI technology. However, China is still behind the US in cutting edge AI science and the development of the field is hampered by a shortage of talents.[84]
Relevant locations in China: the cities of Jinan, Xi'an, Chengdu and Chongqing are designated as trial zones for new-generation AI innovation and development; the Beijing Academy of Artificial Intelligence (BAAI) and the Tianjin New Generation Artificial Intelligence Megaproject, launched in 2018.[85]
Multi-disciplinary initiatives**:** AI - Brain Research (see 4 below)

Opportunities and caveats: In view of China's investment in developing AI and its need for high-level talents as well as the availability of big data, **AI is an attractive area** for collaboration. Opportunities include the areas of AI legislation and governance, e.g. in tackling common challenges such as robot alienation and safety supervision.[86] However,

[80] E.g. EU-China 2020 Strategic Agenda for Cooperation; other documents to consider include: 'Communication on the Global Approach to Research and Innovation (European Commission (2021)) and the Action Plan on Synergies between Civil, Defence, and Space Industries.
[81] State Council of China (2017). 'Next generation artificial intelligence development plan'. For the government supervision and coordination structures for the AI Plan see Cao, Cong (2021, UNESCO), p. 633.
[82] Dai, Sara, (4 March 2020). 'AI is the fastest expanding discipline in China's universities, with 180 more approved to offer it as a major', *SCMP*. The second and third most rapidly expanding disciplines in 2019 were in related fields of new data science and big data technology (138 new programs) and smart manufacturing engineering (80 new programs)
[83] Roberts, H., Cowls, J., Morley, J. *et al.* (2021). 'The Chinese approach to artificial intelligence: an analysis of policy, ethics, and regulation. *AI & Soc* **36,** 59–77).
[84] Robes, Pablo (1 October 2018). 'China plans to be a world leader in Artificial Intelligence by 2030'. *SCMP*.
[85] See e.g. European Commission. Funding Programs in Tianjin. Innovationfunding.eu.
[86] Meltzer, J.P. and Kerry, C.F. (21 February 2021).*'Strengthening international cooperation on artificial intelligence'*. Brookings Institute.

various sub-areas are **vulnerable for dual use applications** and data protection laws as well as ethical and privacy considerations, e.g. with regard to China's surveillance policies, need to be considered.[87] **All collaboration on AI should be preceded by a careful benefit – risk assessment.**

2. Quantum Communications

Quantum technologies offer **possibilities for secure (hack-free) communication,** and the development of superfast computers and highly precision sensors. As a result, quantum technology will find **applications in fields such as defense, finance, and government administration**. China has been strongly investing in quantum[88] technologies in the past years and in some areas it is currently ahead of the US: China has built the world's first quantum satellite and the world's longest quantum communication networks.[89] The Chinese Academy of Sciences and the University of Science and Technology, Hefei, are global leaders in publication output on quantum computing.[90] China's quantum program aims for the development of three disruptive technologies. 1. quantum sensors, which enable high precision detection and measurement of physical disturbances; potential applications are of military relevance and include, for example, airborne sensors that can detect submarines; 2. a quantum computer, enabling superfast calculations; and 3. quantum internet, enabling ultra-secure communication.[91] The field of quantum technology has the attention of President Xi Jinping, who emphasized the great strategic importance of research in this area.[92]
Relevant locations in China**:** the headquarters of China's national quantum program, the Hefei Research Centre for quantum physics, is located in Hefei, Anhui province. Other major players in quantum research include the University of Science and Technology of **China** (USTC), Hefei, and the Chinese Academy of Sciences in Beijing.
Multi-disciplinary approaches**:** Quantum – Integrated Circuits (see 3, below)

Opportunities and caveats: The area of quantum technology is **highly vulnerable to dual use applications** and is also a priority in China's civil-military integration program.[93] **Collaboration in this field is not recommended**.[94]

3. Integrated Circuits

The field of integrated circuits (IC, semi-conductors, chips) powers next-generation technologies in many areas. Becoming self-reliant in this area has been a high priority in China for years and has become even more urgent after US sanctions restricted the supply of chips containing US technology to China. In the period 2015-2020, self-sufficiency in chips has been raised from 10 to 16 percent, but China will not be able to achieve the goal set in its Made in China 2025 plan, of reaching 70 percent self-sufficiency in chips 2025. It

[87] Multiple Chinese companies active in AI-related fields are on the US Entity List (which restricts export and transfer of – among other – S&T) for supporting high tech surveillance against Muslim ethnic minorities in Xinjiang and/or supporting PRC's military modernization programs. See e.g. US Department of Commerce (July 2021). 'Commerce Department adds 34 Entities to the Entity List'.
[88] IDQ. 2018. China's growing investment in quantum computing.
[89] Stefanick, Tom (18 September 2020). 'The state of U.S.-China quantum data security competition.' Brookings Institute; Stephen Chen (29 October 2020). 'How China hopes to win the quantum technology race', *South China Morning Post*. See also CGTN (28 July 2021). 'Chinese Ministry of Science and Technology reveals key fields for future development.
[90] Elseviers. Quantum Computing Research Trends Report.
[91] Chen, Stephen (29 October 2020). 'How China hopes to win the quantum technology race', *South China Morning Post*.
[92] Xinhua (18 October 2020). 'Xi stresses advancing development of quantum science and technology. *People's Daily*.
[93] It is identified as a priority in China's 13th Five-Year Science and Technology Civil–Military Integration Special Projects Plan, see the translation by CSET. See also Nouwens and Legarda (2018).
[94] Interviews with experts in quantum physics (research project for Dutch government and project for Quantum Delta); EU-KNOC 5th Expert Meeting on R&I value chain dependencies on China, 27 May 2021; see also Nouwens and Legarda (2018).

is estimated that by 2025 its self-sufficiency in chips will reach just 19.4 percent.[95] While China is increasing the development and production of indigenous chips and catching up in knowledge, the EU still has the upper hand in the STI value chain of IC. China is **not yet able to develop high-end chip technologies**, the country is estimated to be 7-10 years behind.[96] China lacks high-level researchers in this area and catching up will take time. In 2020, a major initiative to provide more funding to R&D in IC has failed to achieve the desired results as mainly (low-level) domestic semiconductor-related companies jumped upon the occasion to get funding instead of parties that can lead the high-level development of IC technology that China needs,[97] a good example of misuse of funding due to ineffective evaluation of project candidates. More successful in achieving breakthroughs in IC technology may be a recent initiative by two large Chinese companies to build a **quantum chips R&D lab**.[98] In order to increase the number of research talents in IC the Chinese Ministry of Education is currently encouraging universities across the country to establish programs dedicated to fields related to integrated circuits.[99]
Relevant locations in China: Institute of Semiconductors of the Chinese Academy of Sciences in Beijing. A new quantum chip facility will be based in Hefei (Anhui).
Multi-disciplinary initiatives: IC– quantum technology (the Quantum Chip Facility in Hefei is expected to closely collaborate with the Hefei Research Centre for Quantum physics.) IC technology – AI; IC technology – Biotech/life sciences.

Opportunities and caveats: There are opportunities for collaboration, e.g. in the area of chips for medical use (crossroads IC-biotech/life sciences) but there are also considerable risks, e.g. with regard to maintaining EU competitiveness in IC. As the EU is still ahead in developing IC and catching up in IC is a strong priority for China, Chinese stakeholders may have a strong **interest in recruiting high-level experts from abroad** and in **pushing for technology transfer**.[100] In view of China's role in global chip manufacturing collaboration can be beneficial for European stakeholders, but joint projects should be preceded by a **careful benefit–risk assessment**.

4. Brain Science and Brain-like Research

In setting this priority, the 14th FYP builds upon the China Brain Project and mega-plans presented in the 13th FYP and the MLP 2006-2020. The China Brain project takes the form of 'one body - two wings', with the body focusing on understanding the brain, and the two wings covering disease and AI (brain-machine technologies). It combines basic research on neural mechanisms underlying **cognition** with the areas of early **diagnosis and treatment of neural disorders and diseases**, such Alzheimer and depression; and **brain-simulations aimed at advancing AI technology and robotics**.[101] Brain research is still a relatively new and small field in China[102] but is developing very fast, reportedly thanks to Chinese scholars returning from abroad.[103] The country's competitive advantages are thought to lie in its huge population base, which both drives efforts to improve diagnosis and treatment of brain-related diseases and enables big data analyses; and the

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[95] Borak, Masha (19 January 2021). China boosts semiconductor production in 2020, but imports keep apace frustrating self-sufficiency goals. *SCMP*.
[96] To, Yvette (2021). 'China chases semiconductor self-sufficiency.' *East Asia Forum*; and Hille, Kathrin and Sun, Yu (13 October 2020). 'Chinese groups go from fish to chips in new 'Great Leap Forward'. *Financial Times.*
[97] Hille (2020).
[98] Chi, Jinyi (12 April 2021). 'Chinese firms to set up quantum chip R&D lab to catch up with global leaders' *Global Times*
[99] Coco Feng (28 June 2021). 'US-China tech war: mainland universities rush to expand semiconductor programmes in drive for self-sufficiency'. *SCMP.*
[100] EU-KNOC 5th Expert Meeting on R&I value chain dependencies on China, 27 May 2021.
[101] Normile, Dennis (22 May 2018). 'Here's how China is challenging the U.S. and European brain initiatives'. *Science.*
[102] Cao, Cong (UNESCO 2021)
[103] Prof. Lu Bai in: Kuhn, Robert Lawrence (28 February 2019). 'Full Episode – What is "China's Brain Project"? What are its ambitions?'. Podcast CGTN.

use of nonhuman primates, especially monkeys, for close-to-human animal-model testing.[104] In this field China features 'the world's largest supply of laboratory grade non-human primates'.[105] China seeks to make important contribution to the development of therapies, including the use of medical devices, and to the mapping of brain circuits responsible for consciousness. The AI wing of China's Brain Project is part of the country's civil-military integration strategies and is aligned with China's military strategies and rhetoric.[106]
Relevant locations in China: In 2018 China established two institutes in this area: the Chinese Institute for Brain Research in Beijing and the Shanghai Research Centre for Brain Science and Brain-inspired Intelligence. In addition, there is a Centre for Excellence in Brain Science and Intelligence Technology based at the Chinese Academy of Sciences' Institute of Neurology in Shanghai.
Multi-disciplinary initiatives: China is investing strongly in the connection between Brain Science and AI and the development of brain-computer interfaces.[107]

Opportunities and caveats: While not identified by either side as a priority for collaboration, this field may offer **opportunities** for collaboration in areas focusing on **understanding and treating brain related diseases** and the development **of neuro-ethics,** e.g. in the framework of the **International Brain Initiative** (IBI)[108] project of which China and Europe are members. However, **ethical issues,** e.g. a more permissive experimental ethos[109] and restrictions following from recent Chinese legislation (see above) need to be considered when entering collaboration.

5. Gene and Biotechnology

The Chinese government considers this field, which includes areas ranging from drugs research and vaccines to agricultural and military applications, as important for achieving objectives regarding **food and health security, and environmental protection**. Ample investment in this field has led to a rapid development of biotech industries, making China second to the US in terms of size. For example, in the period 2015-2018, academic research in the areas of biomedicine & high-performance medical equipment received the highest funding among China's Made in China 2025 priority areas.[110] In term of quality, Chinese biotech firms have become leading in some areas, for example cancer treatment and genomics, but the country is far from playing a dominant role in biotech R&D.[111] China has invested much in gene sequencing technologies, resulting in global top rankings. DNA samples from around the globe are sent to China for sequencing, giving rise to concerns that China could harvest genetic information from populations around the world and weaponize it.[112] China is a Party to the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization but there are legal obstacles to the implementation of the protocol in China.[113] In recent years China has accelerated the construction of its biosafety/biosecurity legislative regime; in April 2021 **China's Biosecurity Law** went into effect.[114]

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[104] Kuhn, Robert Lawrence (28 February 2019).
[105] Hannas, W. (September 2020). 'China AI-Brain Research'. Center for Security and Emerging Technology (CSET).
[106] Putney, Joy (1 July 2021). 'Neurotechnology for National Defense: the U.S. and China'. *The Cipher Brief.*
[107] For details see, Hannas, W. (September 2020). 'China AI-Brain Research'. Center for Security and Emerging Technology (CSET).
[108] See the IBI website.
[109] *Idem,* p. iii.
[110] Datenna (July 2020). 'Made in China 2025. Industry Policy and Research'. White Paper. Second highest academic funding went to the area of Next Generation IT.
[111] Moore, Scott (April 2020). 'China's Role in The Global Biotechnology Sector and Implications For U.S. Policy.' Brookings.edu.
[112] Needham, Kirsten (5 August 2020). 'Special Report: Covid opens new doors for China's gene giant.' Reuters.
[113] Zheng, Xiaoou (2019). 'Legal challenges and opportunities in the implementation of the Nagoya Protocol: The case of China.'
[114] For more details see e.g. Cao, Cong (2021). 'China's evolving biosafety/biosecurity legislations'. *Journal of Law and the Biosciences*, Volume 8, Issue 1.

Relevant locations in China: China's gene biotechnology R&D takes place at hi-tech zones, universities and in State Key Labs in all Chinese regional S&T clusters: the Beijing-Tianjin-Hebei area, the Yangtze River Delta (incl. Shanghai); and Greater Bay Area (incl. Shenzhen and Hongkong). China's BGI Group, the 'Goliath' in genomics research, is based in Shenzhen but has labs all over China and abroad.
Multi-disciplinary initiatives**:** Gene and Biotechnology **–** ICT; Gene and Biotechnology – Clinical Medicine and Health.

Opportunities and caveats: **biotech sub areas related to ensuring agriculture, food and health security offer good opportunities** for STI collaboration. They are on the EU-China 2020 Strategic Agenda for Cooperation[115] and the two sides agreed in 2017 to develop flagship initiatives in biotechnologies for environment and human health.[116] Although China has tightened its management of biotechnology R&D after the 2018 CRISPR baby scandal,[117] **ethical issues, including privacy of data, need to be considered** when entering collaboration. In addition, there are (legislative) **restrictions on** the **export** and domestic circulation of biological samples and genetic data[118] and there is a **dual-use** side to biotechnologies, some of which can be used for military purposes such as the development of biological weapons.

6. Clinical Medicine and Health

Public health is a national priority in China and the country's research on clinical medicine primarily aims to serve China's societal needs, in particularly in view of its large and rapidly ageing population. In recent years the government has invested in the establishment of national centers for clinical medical research that focus on various common diseases, e.g. cancer and cardio-vascular diseases, in biobanks and databases,[119] and in the cultivation of high-level medical talent.[120] According to a Chinese evaluation, China ranked ninth in the world for clinical research capability in 2017.[121] In various areas, e.g. oncology innovation, China is making rapid progress, as a result of the proliferation of biotech companies, a focused R&D portfolio, and a drive to improve the quality of research.[122] In the area of stem cell research, China ranks among the world top.[123] Another area in which China is a global leader is personalized medicine, focused on genome sequencing and cloud-based genomics. In 2016 China established the China Precision Medicine Initiative, a 15-year program with ample funding, which boosted the country's leading position in personalized medicine.[124]
Relevant locations in China: Beijing: the (merged) Chinese Academy of Medical Sciences (CAMS) and Peking Union Medical College (PUMC), China's largest medical institution and leading in multidisciplinary medical research in China. Tianjin: National Clinical Research Centre for Cancer (at Tianjin Medical University).
Multi-disciplinary initiatives: Clinical Medicine and Health – Biotechnology – Brain Project.

Opportunities and caveats*:* This field is identified by both the EU and China as a **priority for collaboration** as both sides share an interest in tackling health issues. The EU - China

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[115] European External Action Service (2020). EU-China 2020 Strategic Agenda for Cooperation.
[116] See the European Commission webpage on international cooperation with China.
[117] See e.g. State Council (2019), Regulations of the People's Republic of China on the Management of Human Genetic Resources.
[118] See e.g. Cyranisky, David (2018). 'China's crackdown on genetics breaches could deter data sharing.' *Nature* 563, 301-302
[119] Zhang H. (24 July 2017). 'China builds 32 national centers for clinical medical research'. *People's Daily.*
[120] State Council (2020).'China urges innovative development of medical education'
[121] Wu, Yangfeng et al.'China's medical research revolution'. BMJ 2018; 360: k547.
[122] McKinsey (2020). 'Managing China's growing oncology burden'
[123] CGTN (28 July 2021). 'Chinese Ministry of Science and Technology reveals key fields for future development.
[124] Cyranoski, D. (2016). 'China embraces precision therapy'. *Nature* 529(7584).

2020 Strategic Agenda mentions the **areas of antimicrobial resistance, e-health, prevention of cancer** as opportunities for collaboration.
EU research may benefit from the size of medical data and the availability of expensive equipment in China.[125] There are little caveats, although **ethical considerations** need to be addressed and it will be necessary to rapidly **assess the impact of the new Chinese data protection and privacy laws** on scholarly access to data and export of research results.

7. Deep space, deep ground, deep sea and polar exploration

The focus on this group of research fields cannot be separated from **China's geopolitical ambitions**, including concrete political ambitions regarding China's role in the Arctic and in space. Aiming to build an Arctic identity that supports China's claim to have a greater say in Arctic development, polar research not only focuses on topics such polar glaciology, polar oceanographic science and polar biological science, but also on polar politics and security.[126] In space technology China has become a driving force with successes such as the Tianwen-1 Mars mission, the mission to the backside to the moon, and the satellite network Beidou. In deep sea research, China is rapidly rising with research focused on climate change and the uncovering and exploitation of resources including fossil fuels and minerals.[127] Deep ground projects include underground laboratories for dark matter experiments (Chengdu) and storage of high-level radioactive waste (Beishan Underground Research Laboratory, Gobi Desert).[128]
Relevant locations in China: China Aerospace Science and Technology Corporation (CASC)**,** the leading force of China's space technology (and industry) has R&D centers in Beijing, Shanghai, Tianjin, Xi'an, Chengdu, Hong Kong and Shenzhen. In 2021, a Deep Sea Sci-Tech Lab has been established in Wuxi (Jiangsu Province).[129] The Polar Research Institute of China (PRIC), the main player in polar research, is located in Shanghai.
Multi-disciplinary approaches: Space technology – AI – quantum technology.

Opportunities and caveats: collaboration in space research figures on the EU-China 2020 Strategic Agenda for Cooperation but only in a limited number of areas, e.g. in **areas that will contribute to green development**. Collaboration on radioactive waste storage may be beneficial to both sides. The Strategic Agenda calls for enhancing information exchange in areas such as earth observation, geoscience, space exploration and points to exploring collaboration under the framework of the EU-China Space Technology Cooperation Dialogue and the Group of Earth Observation. The area of space technology is a priority in China's Civil-Military Integration programs[130] and is **highly vulnerable to dual use application**.[131]

8. Green Development

Green development is emphasized throughout the 14th FYP. Although the document does not include targets that support China's promise to reach carbon neutrality by 2060, it presents priorities aimed at the improvement of China's energy efficiency, the expansion of renewable energy sources, and the modernization of China's state grid, areas that will support the country's future transition to cleaner energy sources. The emphasis on green

[125] D'Hooghe et al. (2018).
[126] Eiterjord, T.A. (2020). 'Geopolitics of Chinese Arctic Research'. Max Planck Institute.
[127] Zhang, Zhihao (13 August 2021). 'China widely engages in deep-sea research'. *China Daily*.
[128] Zhang, Zhihao (8 April 2021). 'Construction of radioactive waste disposal lab underway'. *China Daily*.
[129] Xinhua (18 January 2021). 'Deep sea sci-tech lab established to boost China's key tech innovation'.
[130] It is identified as a priority in China's 13th Five-Year Science and Technology Civil–Military Integration Special Projects Plan, see the translation by CSET.
[131] For details on military use of space technologies see Nouwens, Meia and Helena Legarda (2018). 'China's pursuit of advanced dual-use technologies' IISS, and Merics. Chapter 3.

development is also reflected in the publication in June 2020 of the 'Master Plan for National Key Ecosystem Protection and Restoration Major Protects (2021-2035)'. This plan sets various ecosystem targets and puts forward nine major ecosystem protection and restoration projects across the country.[132] China is taking big steps forward in greening: in the past five years China has met thirteen of the sixteen green targets set in the 13th FYP (2016-2020). Among the targets not met is a reduction of energy consumption. China is making advances in wind and solar energy, e-mobility, energy conservation, green transportation, water, and waste treatment but needs breakthroughs in technologies such as efficient resource use.[133]

Opportunities and caveats: China's prioritization of green development offers **many opportunities** for STI collaboration. As the EU-China 2020 Strategic Agenda for Cooperation states, both sides have much to share regarding green innovation and the transition to a climate neutral economy and the EU is also investing in low carbon technologies and green tech application.[134] Specific areas mentioned in EU publications and policy documents include:

- New and renewable and energy efficient technologies[135]
- Sustainable urbanization and greener aviation (flagship initiatives)[136]
- Green and sustainable finance[137]
- Circular economy, especially the area of recycling technologies[138]

In developing collaboration, the EU can make good use of the **China-EU Institute for Clean and Renewable Energy**.

There are no major caveats, but the EU is advised to balance its collaboration with China for the greater good of fighting climate change with maintaining its competitive position, e.g. through combining collaboration in developing technologies with a strengthening of the EU's own green industrial and tech base.[139]

Conclusion: promising areas for collaboration

Opportunities for EU-China scientific STI collaboration emanating from the 14th FYP and related recent STI policies are most promising for the EU and EU MS in **areas where interests converge, China is strongly investing, both sides may equally benefit, and risks and vulnerabilities can be handled.**

The eight areas discussed in this chapter are very broad and the sub areas they cover are too wide-ranging to allow for generalizations. Each sub area needs to be discussed and evaluated by specialists in the fields and each potential joint project with China always needs to be assessed in terms of risks and benefits.[140] However, STI stakeholders have long called for an identification of green areas for collaboration. Therefore, with the aim of stimulating discussion on the (im-)possibility of marking green areas for collaboration and

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[132] Policy Summary of the Master Plan for National Key Ecosystem Protection and Restoration Major Protects (2021-2035).

[133] Holzman, Anna en Grunberg, Nils (7 January 2021). '"Greening" China: An analysis of Beijing's sustainable development strategies'. Merics.

[134] EU Commission (7 March 2020). 'Boosting the EU's Green Recovery: Commission Invests € 1 Billion in Innovative Clean Technology Projects'.

[135] EU-KNOC 5th Expert Meeting on R&I value chain dependencies on China, 27 May 2021.

[136] Webpage European Commission/International Cooperation/China.

[137] Anthony, Ian, Yuan, Jingdong and Xia, Sun (2021). 'Promoting China–European Union Cooperation on Green and Sustainable Finance'. Sipri.

[138] EU-KNOC 5th Expert Meeting on R&I value chain dependencies on China, 27 May 2021

[139] Holzman, Anna en Grunberg, Nils (7 January 2021). '"Greening" China: An analysis of Beijing's sustainable development strategies. Merics.

[140] Important EU tools for evaluating potential collaboration are the EU guidelines for Tackling R&I Foreign Interference and EU Export Control Guidelines [Regulation (EU) No 2021/821].

while emphasizing the need for each project to be assessed, this paper suggests a broad categorization of science fields as being less or more prone to risks.

Promising 14th FYP frontier science areas (green) less prone to risks:

- Biotech sub areas related to ensuring agriculture, food and health security
- Clinical medicine and health; Life Sciences
- Green development, circular economy

14th FYP frontier science areas (orange) that are prone to risk but offer many opportunities in sub areas and/or in which collaboration is of strategic importance to Europe:

- Artificial Intelligence
- Integrated Circuits
- Brain Science and Brain-like Research
- Deep Ground

In these areas an in-depth risk-benefit assessment is called for.

14th FYP frontier science areas (red) with important caveats in many sub areas:

- Quantum Communications
- Deep Space
- Polar Exploration

These fields may include sub areas that are safe for collaboration but in general collaboration in these fields is not recommended.

Subnational collaboration

As discussed in chapter 1, many Chinese subnational governments publish their own FYPs and STI plans, and they often have their own funding schemes. This offers additional opportunities for collaboration. An example is provided by a recent joint European-Chinese study, that suggest that promoting innovation at the sub-national level provides a fruitful terrain for cooperation between Europe and China.[141] The EU International Urban and Regional Cooperation program 2021-24 (IURC), which will be implemented from 2021, envisages systematic region-to-region collaboration on innovation. If successful, this may open up new avenues for engagement in STI. Before engaging in subnational projects, it is important to **check if**, in addition to China's national laws and regulations, **extra or different local regulations apply to the collaboration.**

Conclusions and Recommendations

The 14th FYP presents and confirms several policy directions that are relevant to EU-China scientific research collaboration:

- China's goal to achieve **self-reliance** will be the main driver for STI policies and initiatives in the coming years
- China aims to make scientific research better serve the economy and societal needs including achieving Common Prosperity
- China seeks to expand and improve human resources in STI
- China's continued investment in internationalization of STI is focused on serving national strategic goals
- Government and CCP supervision over STI and the role of political ideology will be strengthened

[141] Hassink, Robert, et al (2020). 'EU-China Regional Innovation Joint Study'.

More details on projects will be provided in the National Medium- and Long-term Science and Technology Development Plan for 2021-2035, which is expected to be published later in 2021.

Opportunities for collaboration

Opportunities for EU-China scientific STI collaboration emanating from the 14th FYP and related recent STI policies are most promising for the EU and EU MS in areas where interests converge, China is strongly investing, both sides may equally benefit, and risks and vulnerabilities can be handled. Most promising in this respect are: biotech sub areas related to ensuring agriculture, food and health security; clinical medicine and health and Life Sciences; and Green Development and circular economy.

Recommendations[142]

Conduct in-depth studies of opportunities and caveats of low-risk areas of research by specialists in the field, to start with areas that both the EU and China have put forward as areas for collaboration (the 'promising areas' above).

Conduct research aimed at:

- Identifying opportunities for collaboration emanating from the special (sectoral and theme focused) plans at national level, and 14th FYP plans at subnational levels.[143]
- Gaining more insight into China's R&D funding in STI areas[144]
- Better understanding China's dual use and civil-military integration programs
- Better understanding how Chinese universities work: funding, decision-making, relations/affiliations,

Policy recommendations

In view of the 14th FYP's aim for self-reliance, the strengthening of the role of the CCP, and the expanding legislation in areas that affect STI collaboration, which together may lead to increased interference in STI, EU policy makers are recommended to:

- Put reciprocity, level-playing field, ethics and science integrity standards high on the agenda in talks with China
- Raise the level of China knowledge among politicians and policymakers and hire or engage policymakers with relevant S&T backgrounds (mainstream China issues)
- Monitor and exchange information on China's 'cherry-picking'[145] in STI collaboration with EU MS

For EU MS STI stakeholders at various levels:

- Avoid dependency on China, diversify collaboration
- Make better use of the knowledge of EU researchers in China, as they are the ears and eyes for the EU in China. This can be achieved through developing national networks of researchers working in or with China, and sharing information with peer institutions
- Encourage Implementation of the EU Guidelines on Tackling R&I Foreign Interference[146] and facilitate risk-benefit assessments.

[142] Based on EU-KNOC expert meetings in 2020-2021, EU-KNOC recommendation papers and in publications used in this study.
[143] See also Horvat, Manfred (2021). Understanding and analysing China's five-year development plan system'. Final Report – Short Synthesis. EU-China Partnership Facility (ECPF).
[144] Idem; and EU-KNOC experts meetings.
[145] if one country is not willing to cooperate with China on Chinese terms, China often moves on to the next country to try (EU-KNOC Expert meeting).
[146] The Guidelines are expected to be published in Autumn 2021. See also Klueting, Laura et al. (March 2021). 'Analysis of current and publicly available documents on securing international science cooperation'. EU Research and Innovation Knowledge Network on China.

Appendix: Box 1 of the 14th FYP period: Main indicators.

Category	Index	2020 年	2025 年	Annual average/ cumulative	Attributes
Main indicators of economic and social development during the "14th Five-Year Plan" period (Box 1)[147]					
Economic Develop-ment	1. Gross domestic product (GDP) growth (%)	2.3	—	Keep it in a reasonable range, and propose each year as appropriate	Expected /indicative
	2. Overall labor productivity growth (%)	2.5	—	Higher than GDP increase	Indicative
	3. Urbanization rate of permanent population (%)	60.6*	65	—	Indicative
Innovation	4. Growth in R&D expenditures of the whole society (%)	—	—	Growth >7, aim to invest more intensively than in the 13th FYP	Indicative
	5. The number of high-value invention patents per 10,000 people (pieces)	6.3	12	—	Indicative
	6. Digital Economy share of GDP	7.8	10	—	Indicative
People's livelihood and Well-being	7. Growth in per capita disposable income (%)	2.1	—	Largely in line with GDP growth	Indicative
	8. Urban survey unemployment rate (%)	5.2	—	＜5.5	Indicative
	9. Average years of education of working-age population (years)	10.8	11.3	—	Binding
	10. The number of licensed (assistant) physicians per thousand population (persons)	2.9	3.2	—	Expected
	11. Basic pension insurance participation rate (%)	91	95	—	Expected
	12. The number of nurseries for infants under 3 yrs old per thousand population (units)	1.8	4.5	—	Expected
	13. Average life expectancy (years)	77.3*	—	〔1〕	Expected

147 Note: ① [] is the cumulative number in 5 years. ②The data marked with * are for 2019. ③ Comprehensive energy production capacity refers to the sum of coal, oil, natural gas, and non-fossil energy production capacity. ④ In 2020, the ratio of days with good air quality in cities at prefecture level and above and the index value of the ratio of surface water reaching or better than Class III water bodies are affected by factors such as the new crown pneumonia epidemic, and are significantly higher than normal years. ⑤The total labor productivity growth of 2.5% in 2020 is the expected figure.

Green Ecology	14. Reduction in energy consumption per unit of GDP (%)	—	—	〔13.5〕	Binding
	15. Reduction of carbon dioxide emissions per unit of GDP (%)	—	—	〔18〕	Binding
	16. The ratio of days with good air quality in cities at prefecture level and above (%	87	87.5	—	Binding
	17. Proportion of surface water reaching or better than Class III water body (%)	83.4	85	—	Binding
	18. Forest coverage rate (%)	23.2*	24.1	—	Binding
Safety Guarantee	19. Comprehensive grain production capacity (100 million tons)	—	＞6.5	—	Binding
	20. Comprehensive energy production capacity (100 million tons of standard coal)	—	＞46	—	Binding