

## Prospects and Countermeasures for Cooperative Development of Uranium Resources between China and Central Asia under the Silk Road Economic Belt (Postprint)

**Authors:** Mao Hanying, Qu Jiansheng, Li Yaoming, Bao Shaoyong

**Date:** 2018-06-24T00:00:00+00:00

### Abstract

Kazakhstan and Uzbekistan in Central Asia constitute one of the world's major uranium resource enrichment zones, featuring large reserves, concentrated distribution, and favorable mining conditions. Since 2009, Central Asia's uranium mining output has long ranked first in the world, accounting for 43.5% of total global uranium production in 2016 (with 91% distributed in Kazakhstan). China-Central Asia uranium cooperation began in 2005 and has developed rapidly since 2010. The article analyzes the necessity and feasibility of cooperative uranium development between China and Central Asia, expounds on the evolution of cooperative development models from uranium trade and exploration-development to nuclear fuel assembly processing, and provides projections for the prospects of cooperative development. The primary conclusions indicate: before 2030, Central Asian uranium can meet 70%-75% of China's demand for imported natural uranium required for nuclear power development; thereafter, with the rapid depletion of Central Asian uranium resources, the degree of supply security will decrease to 40%-50% by 2035. Finally, the article puts forward countermeasures and suggestions for strengthening and deepening China-Central Asia uranium cooperation: using the "Five Connectivities" concept to guide cooperative development, expeditiously compiling the "Outline Plan for China-Central Asia Uranium Cooperative Development," identifying focal points for future cooperative development, continuously elevating the status and role of Chinese enterprises in collaborative development, and attaching importance to preventing and mitigating risks in cooperative development.

## Full Text

### Preamble

**Special Topic: “Silk Road Economic Belt” Central Asia Energy Geo-configuration and National Security**

**Prospects and Countermeasures for China-Central Asia Uranium Mining Cooperative Development in the Silk Road Economic Belt**

Mao Hanying<sup>1\*</sup>, Qu Jiansheng<sup>2</sup>, Li Yaoming<sup>3</sup>, Bao Shaoyong<sup>1</sup>

(1 Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China;

2 Lanzhou Documentation and Information Center, Chinese Academy of Sciences, Lanzhou 730000, China;

3 Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi 830011, China)

### Abstract

Kazakhstan and Uzbekistan in Central Asia are among the world's most uranium-rich regions, characterized by large reserves, concentrated distribution, and favorable mining conditions. Since 2009, Central Asia has consistently ranked first globally in uranium production, accounting for 43.5% of world output in 2016 (with 91% distributed in Kazakhstan). China-Central Asia uranium cooperation began in 2005 and accelerated after 2010. This paper analyzes the necessity and feasibility of cooperative uranium development, outlines the evolution from trade to exploration and nuclear fuel component processing, and forecasts development prospects. The main conclusions are: before 2030, Central Asian uranium can meet 70-75% of China's imported natural uranium demand for nuclear power development; thereafter, rapid resource depletion will reduce this guarantee to 40-50% by 2035. Finally, the paper proposes strategies to strengthen cooperation: guiding development through the “five links” concept, promptly drafting a China-Central Asia Uranium Cooperation Development Plan, clarifying future priorities, enhancing Chinese enterprises' role, and managing cooperation risks.

### Keywords

China, Central Asia, uranium mining, cooperative development, prospects, countermeasures

Uranium is an extremely rare radioactive element that serves as fuel for clean nuclear energy and as raw material for nuclear weapons production through highly enriched uranium and plutonium reprocessing. As a strategically vital resource, uranium plays a special role in national security, greenhouse gas reduction, and climate change mitigation. Since World War II, uranium resources have been a primary target of competition among major powers including the US, Soviet Union/Russia, Japan, and the EU. In 2015, global natural uranium demand reached 63,400 tons, with the US accounting for 28.6%, the EU 29.5%, Russia 9.9%, China 8.4%, and South Korea 7.9%[1]. During the Cold War, the Soviet

Union and US stockpiled large quantities of uranium ore ( $UO_2$ ) and enriched uranium to meet military needs.

The average uranium content in Earth's crust is only 2 parts per million, with highly uneven distribution. According to the International Atomic Energy Agency (IAEA) and OECD's 2016 Red Book, as of January 2015, global identified uranium reserves (<130 USD/kg recovery cost) totaled 5.7184 million tons, with Australia (29.1%), Kazakhstan (13.0%), Canada (8.9%), Russia (8.9%), South Africa (5.6%), and Niger (5.1%) comprising 70.6% of the total[1,2].

Global uranium mining is also highly concentrated. In 2016, world uranium production reached 62,027 tons (equivalent to 73,148 tons  $UO_2$ ), with Kazakhstan (39.6%), Canada (22.6%), and Australia (10.2%) accounting for 72.4% of output[1,2].

### 1.1.1 Large Uranium Resource Reserves

Central Asian uranium reserves (<130 USD/kg recovery cost) amount to 1.52 million tons, representing 19% of world reserves, of which identified reserves total 745,300 tons (13% of global identified reserves at this cost level)[1,3-5]. More than 50 uranium deposits have been discovered, primarily in central-southern and southern Kazakhstan, with three mining districts currently operational.

- (1) **Chu-Sarysu Uranium District:** Located in the upper Chu River and lower Sarysu River basins of central-southern Kazakhstan, in the western Moyynqum Desert. Reserves total 890,000 tons, about 58.5% of Kazakhstan's total[5]. The northern sector includes East, Central, and West Mynkuduk, Inkai, and Budenovskoye deposits with 750,000 tons (84.3% of the district), while the eastern sector contains Tortkuduk, Moinkum, and Kanzhugan deposits with 140,000 tons.
- (2) **Syrdarya Uranium District:** Located along the lower Syrdarya River in southern Kazakhstan, with 250,000 tons (16.4% of national reserves)[5]. The western sector includes Kharasan 1 and 2, Karamurun, and Irkel deposits totaling 180,000 tons, while the southern sector contains Zarechnoye and South Zarechnoye deposits with 70,000 tons.
- (3) **North Kazakhstan Uranium District:** Located 150 km northeast of Astana, with Semizbay and Vostok Zvezdnoye deposits totaling 256,000 tons (16.8% of national reserves)[5].
- (4) **Other Districts:** The Ili River-Balkhash district in southeastern Kazakhstan holds 102,000 tons (6.7% of reserves), and the Mangghystau district on the Caspian coast contains 24,000 tons (1.6%)[5]; neither is currently mined.

### 1.1.2 Concentrated Uranium Resource Distribution

Kazakhstan's total uranium reserves (identified + predicted) make it one of the world's richest uranium regions. Central Asian uranium ore grades generally range 0.05–0.10%. Among Kazakhstan's 18 operating mines, the lowest grade is 0.03% and the highest reaches 0.204% (North Kharasan Mine No. 1)[3].

Uzbekistan's uranium deposits occur primarily along the southern margin of the Kyzylkum Desert in central-northern Uzbekistan. According to the State Committee for Geology and Mineral Resources, identified reserves total 185,800 tons, with prospective resources of 242,700 tons. Deposits are concentrated in a 400 km northwest-southeast belt from Uchkuduk to Nurabad, divided into northern, central, and southern sectors, with major districts at Uchkuduk, Bukantausky, Zarafshan, Zafarabad, and Nurabad[6,7].

### 1.1.3 Predominance of Sandstone-Type Uranium Deposits

Sandstone-type uranium deposits form in clastic rocks like sandstone and conglomerate through epigenetic processes, typically occurring in sedimentary basins. In Kazakhstan's <130 USD/kg identified reserves, sandstone-type deposits account for 93.3%, with the remainder being phosphate and metamorphic types[4]. In Uzbekistan, sandstone-type deposits comprise 74.7% of <130 USD/kg identified reserves, with black shale-type deposits making up 25.3%. Sandstone-type deposits are generally large-scale and suitable for mass mining[7].

## 1.2 Current Status of Central Asian Uranium Resource Development

### 1.2.1 Large-Scale Mining with World-Leading Output

Large-scale uranium mining in Central Asia began in the 1970s. During the Soviet era, Uzbekistan's annual uranium output peaked at 3,800 tons. In the 1990s, as Kazakhstan commissioned new mines, production surged from less than 3,000 tons before 2000 to 6,837 tons in 2005 and 16,449 tons in 2009 (32.4% of world output), ranking first globally ever since. In 2016, Central Asian uranium production reached 26,979 tons (43.5% of world total), with Kazakhstan producing 24,575 tons (39.6% of world output and 91.1% of Central Asia's total)[1,2].

### 1.2.2 In-Situ Leaching Dominates with Low Production Costs

With sandstone-type deposits exceeding 70% of reserves, Central Asian uranium mining primarily employs low-cost in-situ leaching, which offers lower production costs, shorter construction cycles, and environmental benefits (no surface vegetation or soil structure disturbance) compared to conventional underground or open-pit mining. In 2014, approximately 50% of Kazakhstan's uranium was

mined at costs below 78 USD/kg, with 28% at 78–130 USD/kg, while the international spot price averaged 94 USD/kg, giving Central Asian products strong market competitiveness[4,8-10].

### 1.2.3 Concentrated Mine Distribution with Large Scale

Kazakhstan operates 18 uranium mines, nine of which are large-scale producers (>1,000 tons/year), mainly in the Chu-Sarysu region of central-southern Kazakhstan. This region's eastern and northern sectors comprise 11 mines that produced 18,313 tons in 2015 (76.9% of national output). The Syrdarya region in southern Kazakhstan has five large mines that produced 5,034 tons in 2015 (21.2% of national output). The northern Aktau district, developed more recently, has only two operational mines: Semizbay and Zharpek (Vostok Zvezdnoye)[4,5,10].

Uzbekistan operates 13 uranium mines. The northern Uchkuduk mine (commissioned 1964) and southern Nurabad mine (commissioned 1966) each have 800 tons/year capacity, while the central Zafarabad mine (commissioned 1968) has 2,100 tons/year capacity. All ore is processed at the Navoi Mining and Metallurgical Complex with a design capacity of 3,000 tons/year (U O)[3,6,7].

### 1.2.4 All Uranium Exported, with China and Russia Accounting for Over 70%

As neither Kazakhstan nor Uzbekistan operates nuclear power plants, all mined uranium is exported. Before 2010, export destinations were relatively diversified, including Russia, the EU (mainly France), the US, China, Japan, and South Korea. Since 2010, accelerated China-Central Asia cooperation has made China the region's largest uranium importer. According to UN Comtrade data, of Kazakhstan's 28,700 tons of natural uranium exports in 2015, China accounted for 49.5%, Russia 21.8%, France 11.3%, Canada 8.2%, the US 4.8%, and Kyrgyzstan 3%[11], with China and Russia together comprising 71.3%. Uzbekistan exports primarily to China, France, the US, and Russia, with China accounting for approximately 60%[12].

### 1.2.5 State-Controlled Mining with 40% Foreign Participation

In Kazakhstan, uranium mining is controlled by Kazatomprom (Kazakhstan Atomic Industry Company). In 2014, Kazatomprom accounted for 60% of production (13,601 tons), while foreign joint ventures contributed 40% (9,180 tons)[1,10,13]. Major foreign companies include Canada's Uranium One and Cameco, France's Areva, Russia's ARMZ, Japanese companies (Japan Energy, Sumitomo, Kansai Electric), and China's CNNC and CGN. In Uzbekistan, the State Committee for Geology and Mineral Resources monopolizes exploration, development, and exports, with foreign partners including South Korea's power and nuclear companies and China's CGN.

## 2.1 Necessity of Cooperative Development

### 2.1.1 China' s Uranium Resources Far from Meeting Domestic Needs

China is not uranium-rich. Despite substantial investment in uranium exploration since 2005 that discovered new deposits in the Yili and Tuha basins of Xinjiang, the Dongsheng and Erlian basins of Inner Mongolia, and the Songliao Basin in Northeast China, China' s uranium reserves and global share remain limited. According to the IAEA' s 2016 Red Book, as of January 2015, China' s identified uranium reserves (<130 USD/kg recovery cost) totaled 272,500 tons (4.8% of world reserves), ranking ninth globally; proven reserves were 128,300 tons and inferred reserves 144,200 tons, representing 3.7% and 6.4% of world totals respectively[1]<sup>1</sup>.

China also faces several unfavorable conditions[14-16]: (1) Complex metallogenic conditions and deposit types, including granite, volcanic, sandstone, and carbon-siliceous-argillite types accounting for 38%, 22%, 19.5%, and 16% of reserves respectively; (2) Low ore grades, with over half being low-grade ore containing <0.1% uranium, often associated with sulfur, phosphorus, and other metals; (3) Small deposit sizes, with medium and small deposits comprising over 60% of total reserves, and granite-type deposits averaging <500 tons; (4) Poor occurrence conditions, such as deep burial and variable wall rock lithology. Only 24% of identified reserves are amenable to in-situ leaching (versus 46% world average in 2014), with most requiring underground mining[15,16]. These factors result in poor construction conditions, high unit investment, and elevated mining costs.

### 2.1.2 China' s Nuclear Fuel Demand Will Continue Rapid Growth for 20-30 Years

As clean energy, nuclear power represents a major direction for global new energy development. As a responsible major power, China has actively participated in international climate negotiations since the early 1990s, including the UN Framework Convention on Climate Change, Kyoto Protocol, Copenhagen Accord, and Paris Agreement. At the 2009 Copenhagen Conference, China pledged to reduce CO<sub>2</sub> emissions per unit GDP by 40-45% from 2005 levels by 2020, building on the 46% reduction achieved from 1990-2005. Under the 2015 Paris Agreement, China committed to increase non-fossil energy to 20% of primary energy consumption by 2030 and peak CO<sub>2</sub> emissions around 2030.

To achieve these goals, China' s 12th Five-Year Plan (2011) proposed steadily developing nuclear power in coastal and central provinces, with 40 GW under construction. The 13th Five-Year Plan (2016) set targets of 58 GW operating and 30 GW under construction by 2020 (4% of generation). By end-2016, mainland China had 35 operating reactors (33.63 GW, 2.04% of installed capacity; 213.2 TWh generation, 3.56% of total) and 21 under construction (23.44 GW) (China Energy News, 2017-03-09). The National Energy Administration' s nuclear power 13th Five-Year Plan projects 120-150 GW installed capacity

by 2030, raising nuclear generation' s share to 8-10% (China Economic Herald, 2016-07-22). Based on technical-economic indicators for new and operating gigawatt-scale reactors (initial fuel load 400 tons natural uranium; annual refueling 175 tons), natural uranium demand will reach 11,000-11,500 tons in 2020 and 24,000-25,000 tons in 2030[16-19]<sup>2</sup>, with import dependence rising to 65% and 77% respectively[20].

## 2.2 Feasibility Analysis

### 2.2.1 “Five Links” Concept Guides Cooperation

At the May 2017 Belt and Road Forum, President Xi Jinping emphasized that advancing Belt and Road cooperation requires the “five links” : policy coordination, infrastructure connectivity, unimpeded trade, financial integration, and people-to-people bonds, to build a path of peace, prosperity, openness, innovation, and civilization. China-Central Asia uranium cooperation, as a major Belt and Road component, must be guided by these principles. Policy coordination is critical, focusing on establishing communication mechanisms with Kazakhstan and Uzbekistan (including state-owned enterprises) to build political trust, deepen interest alignment, and jointly formulate cooperation policies, plans, and measures. Infrastructure connectivity should prioritize linking and upgrading transport, energy, communications, water supply, and environmental infrastructure to address backward conditions. Unimpeded trade should promote whole-industry-chain cooperation, especially in uranium processing, R&D, and trade. Financial integration, given uranium exploration' s long cycles and large investments, should leverage the AIIB, Silk Road Fund, and bilateral financial institutions for multilateral funding. People-to-people bonds should improve local livelihoods through cooperation in education, culture, science, technology, health, disaster prevention, and poverty reduction, creating local benefits.

### 2.2.2 Need for Production Capacity Cooperation

In building the Silk Road Economic Belt, production capacity cooperation is essential, bringing tangible benefits to partner countries through economic development, job creation, and improved livelihoods while enabling China' s competitive industries (steel, equipment manufacturing, nonferrous metallurgy, building materials, chemicals, textiles) to expand internationally. China possesses mature, advanced technologies and production capacity in uranium exploration, nuclear fuel component manufacturing, and nuclear power plant construction, as exemplified by the domestically developed third-generation “Hualong One” reactor commissioned in 2016. Through production capacity cooperation with major Central Asian uranium producers, both sides can enhance local exploration and development technology, extend industry chains, improve comprehensive economic returns, and boost international competitiveness while meeting China' s natural uranium demand—achieving mutual benefit.

### 2.2.3 Favorable Cooperation and Investment Environment

- (1) **Established Nuclear-Free Zone:** During the Soviet era, Kazakhstan hosted nuclear weapons tests and stored large arsenals. After independence, President Nazarbayev declared Kazakhstan a non-nuclear state in May 1992, signed the Nuclear Non-Proliferation Treaty in December 1993, and dismantled all test facilities. In September 2002, Central Asian states agreed to establish a Central Asian nuclear-free zone, signing the treaty in Semipalatinsk, Kazakhstan in September 2006, which does not prohibit peaceful nuclear use.
- (2) **Relatively Stable Political Environment:** Since independence in 1991, Kazakhstan and Uzbekistan have maintained stable political systems. Both pursue independent foreign policies of good-neighborliness with Central Asian neighbors and China while resisting Western influence, providing a reliable foundation for attracting foreign investment and uranium cooperation.
- (3) **Generally Favorable Investment Climate:** Post-independence, both countries opened to foreign investment, making the attraction of foreign capital, technology, and talent long-term priorities. Kazakhstan enacted the Foreign Investment Law (December 1994), State Support for Direct Investment Law (February 1997), and the Investment Law of the Republic of Kazakhstan (January 2003). Uzbekistan promulgated its Foreign Investment Law and Law on Guarantees of Foreign Investment, supplementing them in 2012 with Additional Measures to Promote Foreign Direct Investment, providing land use rights and tax incentives that facilitate accelerated uranium cooperation.
- (4) **Significantly Improved Hard Infrastructure:** Since 2010, Kazakhstan and Uzbekistan have substantially improved transport, communications, energy, and water supply infrastructure. Kazakhstan built railways, power lines, communications, and water pipelines from Taraz to the Chu-Sarysu uranium district and from Turkestan to the Syrdarya district; Uzbekistan completed similar infrastructure from Navoi to the Uchkuduk uranium district, enabling large-scale cooperation.

## 2.3 Main Cooperation Models

China-Central Asia uranium cooperation began in 2005, lagging Western countries by nearly a decade but progressing rapidly to achieve win-win outcomes: Kazakhstan and Uzbekistan accelerate uranium development and local socioeconomic development, while China enhances nuclear power resource security. Five main cooperation models exist[21]:

### 2.3.1 Loan-for-Uranium Model

To ensure long-term stable uranium supply, CNNC and CGN signed “loan-for-uranium” agreements with Kazatomprom and Uzbekistan’s State Committee, providing funding for expanded uranium development that is repaid through uranium deliveries over 8-10 year agreements.

### 2.3.2 Production Sharing Model

With Kazakhstan and Uzbekistan retaining uranium resource ownership and 专营 rights, CNNC and CGN sign agreements to fund exploration and development, recovering costs and sharing production from development benefits.

### 2.3.3 Joint Venture Model

Before constructing new mines, CNNC and CGN form joint ventures with Kazatomprom (typically 51% Kazakh, 49% Chinese ownership) as independent legal entities engaged in exploration, development, production, transport, and sales, with both parties sharing operational risks and tax liabilities. Examples include the Semizbay and Vostok Zvezdnoye joint ventures in North Kazakhstan.

### 2.3.4 Technical Services Model

Leveraging technological, knowledge, and management advantages, CNNC and CGN cooperate with Kazatomprom and Uzbekistan’s State Committee to provide advanced equipment and management experience for exploration, development, processing, and transport, enhancing overall uranium development levels.

### 2.3.5 Whole Industry Chain Cooperation Model

To improve comprehensive economic benefits and international influence, President Nazarbayev proposed in 2009 transforming Kazakhstan from a uranium resource exporter to an “international fuel bank.” This requires advancing whole-industry-chain cooperation from uranium development to nuclear fuel component production and nuclear power plant construction (First Financial Daily, 2017-06-12). Under this vision, CNNC and CGN signed whole-industry-chain agreements proposing a “three-step” strategy: beginning with uranium trade, expanding to joint exploration, then extending to fuel component production and reactor construction. A fuel component joint venture established in December 2015 began construction the following year, preparing for future nuclear power plant cooperation.

## 3. Prospects for Central Asian Uranium Development

Future Central Asian uranium cooperation scale depends primarily on the reserve-to-production ratio of remaining recoverable reserves—the ratio of remaining reserves to annual output—which forms the basis for production

forecasts. Investment scale and long-term low uranium prices due to overcapacity should also be considered, though these uncertain factors serve only as reference points.

Forecasts based on Kazakhstan and Uzbekistan's 2015 identified reserves (<130 USD/kg recovery cost) yield two scenarios: (1) Using a typical 30-year reserve-to-production ratio and accounting for 20% mining losses, average annual output would be 24,200 tons, sustaining mining until 2045; (2) Using a 35-year ratio, annual output would be 20,800 tons, lasting until 2050. Incorporating investment and market price factors, production is predicted to reach 28,000 tons in 2020, 25,000 tons in 2025, 22,000-24,000 tons in 2030, and fall below 20,000 tons by 2035. Declining output will come exclusively from Kazakhstan, while Uzbekistan maintains 3,000 tons/year[1].

### 3.1 Uranium Import Guarantee for China's Nuclear Development

Regarding China's future nuclear power uranium demand, CNNC experts calculate that based on new gigawatt-scale reactors requiring 400 tons of natural uranium for initial fuel loads and 175 tons for annual refueling, China's natural uranium demand will reach 11,000 tons in 2020 (domestic production 4,000 tons, overseas development 8,400 tons, deficit 2,600 tons), 18,500 tons in 2025 (domestic 5,000 tons, overseas 6,900 tons, deficit 10,900 tons), and 24,000 tons in 2030 (domestic 5,500 tons, overseas 13,100 tons, deficit 10,900 tons) (Figure 1 [Figure 1: see original paper]).

Before 2007, China's uranium imports were dispersed among Canada, Australia, Kazakhstan, Namibia, Niger, and Uzbekistan. Since 2010, accelerated China-Central Asia cooperation has made China the region's primary export destination. From 2010-2015, China imported 92,476 tons of natural uranium from Central Asia, representing 51.3% of the region's total exports[11,12]. UN Comtrade data show that during 2010-2016, China imported 140,000 tons of natural uranium, with Kazakhstan supplying 67% and Uzbekistan 10%, totaling 77%[11,12].

Building on deeper cooperation and maintaining current import levels (2010-2015 average: 17,100 tons/year), Kazakhstan and Uzbekistan could plausibly supply China with 16,000-18,000 tons of natural uranium annually before 2030, meeting 70-75% of China's nuclear power uranium import needs[11,12]. After 2030, as Kazakhstan depletes 70% of its identified reserves and China's nuclear expansion continues, this guarantee will drop to 40-50% by 2035, necessitating early identification of alternative uranium sources.

## 4. Countermeasures to Strengthen China-Central Asia Uranium Cooperation

### 4.1 Guide Cooperation with the “Five Links” Concept

At the Belt and Road Forum, President Xi emphasized that advancing Belt and Road cooperation requires the “five links” to build a path of peace, prosperity, openness, innovation, and civilization. China-Central Asia uranium cooperation must be guided by these principles. **Policy coordination** is critical for establishing communication mechanisms with Kazakhstan and Uzbekistan (including state-owned enterprises) to build political trust, deepen interest alignment, and jointly formulate cooperation policies, plans, and measures. **Infrastructure connectivity** should prioritize linking and upgrading transport, energy, communications, water supply, and environmental infrastructure to address backward conditions. **Unimpeded trade** should promote whole-industry-chain cooperation, especially in uranium processing, R&D, and trade. **Financial integration**, given uranium exploration’s long cycles and large investments, should leverage the AIIB, Silk Road Fund, and bilateral financial institutions for multilateral funding. **People-to-people bonds** should improve local livelihoods through cooperation in education, culture, science, technology, health, disaster prevention, and poverty reduction, creating local benefits.

### 4.2 Promptly Compile the “China-Central Asia Uranium Cooperation Development Plan Outline”

Strengthening strategic alignment with partner countries is a key Belt and Road principle. At the August 17, 2016 Belt and Road symposium, President Xi stressed “earnestly advancing plan implementation with meticulous organization and precise effort.” Therefore, China should strengthen alignment between its 13th Five-Year Nuclear Power Development Plan and Kazakhstan’s and Uzbekistan’s medium- and long-term uranium development plans, promptly compiling the “China-Central Asia Uranium Cooperation Development Plan Outline.” The outline should include cooperation guidelines, principles, objectives, key areas (sectors, regions, and projects), cooperation models and mechanisms, near- and medium-term priority project planning and evaluation, and safeguard measures to serve as the scientific basis for deepening cooperation.

### 4.3 Identify Future Cooperation Priorities

In uranium exploration, priority should focus on: (1) the northern sector of Kazakhstan’s Chu-Sarysu district to improve resource identification, particularly <130 USD/kg recoverable reserves; (2) expanding the Aktau district to increase recoverable reserves; and (3) exploring Uzbekistan’s Kyzylkum Desert district for low-cost sandstone-type uranium.

In uranium development, priority should target districts with large reserves and development potential, such as the Inkai district in Chu-Sarysu’s north-

ern sector (including Inkai 1, 2, 3, and South Inkai), which has identified recoverable reserves of 319,300 tons at 0.052-0.056% grade and 2015 capacity of 4,280 tons[1,13]. With a favorable reserve-to-production ratio, this district could achieve annual capacity of 10,000-12,000 tons, making it a priority cooperation target.

In natural uranium processing, priority should be given to jointly constructing nuclear fuel component enterprises to achieve Kazakhstan's long-sought transition from raw material supplier to higher-value-added nuclear fuel supplier, while tangibly improving China's nuclear material security.

#### **4.4 Continuously Enhance Chinese Enterprises' Status in Cooperation**

As the main Chinese participants, CNNC and CGN currently focus on uranium import trade, with cooperation levels requiring elevation. In 2015, Chinese companies held only two of Kazakhstan's 18 uranium mines and two of 11 uranium joint ventures, controlling just 53,900 tons of reserves and 2,200 tons/year capacity (<10% of national total)[1,10,13], which is extremely unfavorable for long-term stable supply.

Moving forward, China should leverage strong geopolitical and geo-economic relations to advance Belt and Road production capacity cooperation, particularly capitalizing on Kazakhstan's current need for foreign investment to advance uranium sector reforms (e.g., the government's May 2018 plan to sell 25% of Kazatomprom shares). Chinese enterprises should fully utilize capital, technology, and management advantages through joint ventures, equity participation, mergers, and acquisitions to achieve, by 2030, Chinese-controlled uranium capacity accounting for 20-25% of Kazakhstan's total and 40-50% of all foreign companies' total capacity.

#### **4.5 Substantially Build Natural Uranium Product Reserves**

Nuclear power plants require uranium reserves (inventories) for safe operation—typically 5-8 years of resources—to cope with supply disruptions and price surges. Given uranium's high energy density and small storage footprint, uranium reserves are far more secure than conventional fossil fuel stockpiles. The US, Russia, Japan, EU, and others established uranium reserve systems in the 1960s with large inventories. IAEA data reveal Russia's Soviet-era stockpiles of 615,000 tons of natural uranium and uranium products, with annual sales of 30-40 million pounds UO<sub>2</sub> to international markets since 2013, plus 24 million pounds UO<sub>2</sub> equivalent of weapons-derived highly enriched uranium (2015). In 2013, the US national stockpile contained 46,000-56,000 tons of uranium products (natural UF<sub>6</sub>, enriched UF<sub>6</sub>), with commercial inventories and 114,000 tons of >0.34% U-235 depleted uranium tails. EU and Japanese nuclear enterprises hold 53,000 and 45,000 tons of uranium equivalent inventories, respectively.

For China, with high uranium import dependence, building reserves is more critical. Following the 2011 Fukushima incident, international uranium prices

remained low at US\$20-40/pound, offering China an opportunity to expand natural uranium stockpiles. UN Comtrade data show China imported 140,000 tons of natural uranium during 2010-2016, averaging 20,000 tons/year. After deducting consumption, China's actual uranium inventory exceeded 100,000 tons by 2016.

Long-term, uranium's scarcity and continued global nuclear development will likely drive prices to fluctuate upward, potentially reaching or exceeding US\$100/pound (the 2007 peak was US\$136/pound)[5,8,22]. China should seize current low prices to continue large-scale purchases of natural uranium, uranium concentrates, and other uranium products to build national strategic and commercial reserves, targeting 150,000-200,000 tons by 2020—sufficient for 8-10 years of future nuclear power development.

#### 4.6 Emphasize Risk Prevention and Mitigation in Cooperation

Major risks in China-Central Asia uranium cooperation include: (1) **Political risks:** Central Asia is a Muslim-majority region where cultures intersect and collide, with complex ethnic and religious issues. Religious extremist and international terrorist forces, such as the “Islamic Movement of Uzbekistan” and “Hizb ut-Tahrir,” pose threats to uranium cooperation. (2) **Economic risks:** Uranium cooperation involves long construction cycles, large investments, and slow capital recovery. Geological exploration from reconnaissance to reserve submission requires 10 years, followed by 4 years of mine construction. International financial fluctuations and changing foreign investment policies and incentives increase investment risks. (3) **Ecological risks:** Most Central Asian uranium districts lie on desert margins with arid climates, scarce precipitation, and fragile ecosystems. Large-scale in-situ leaching may contaminate surface and groundwater, affecting surrounding settlements.

Therefore, cooperation must emphasize risk prevention and mitigation. At the governmental level, establish leadership summits and regular consultations and policy coordination to actively prevent and resolve non-commercial risks (security, political, ecological), while guiding enterprises to guard against macro-market and financial risks and improving response mechanisms. At the project investment decision-making level, strengthen comprehensive research on uranium metallogenic geological backgrounds, conditions, and regularities to accurately assess development feasibility and potential, while comprehensively studying investment soft and hard environments to understand host countries' mining policies, laws, and regulatory and implementation risks. At the enterprise level, focus on preventing operational and technical risks while attending to social, cultural, and security risks.

---

#### References

[1] International Atomic Energy Agency. *Uranium 2016: Resources, Production*

*and Demand*. Vienna: IAEA, 2016.

[2] World Nuclear Association. *Nuclear Power in Kazakhstan*. [2018-06-05]. <http://world-nuclear.org/information-library/country-profiles/countries-g-n/kazakhstan.aspx>.

[3] Yan Qiang, Wang Jian' an, Wang Gaoshang. Overview of China' s uranium resources and demand forecast for 2030. *China Mining Magazine*, 2011, 20(2): 1-5.

[4] Zeng Yijun. Innovating uranium metallurgy technology to support large base construction. *China Nuclear Industry*, 2015, (11): 25-27.

[5] Liu Ting, Liu Qiaofeng. Global uranium resources status and nuclear energy development trends. *Modern Mining*, 2012, (4): 24-26.

[6] Dai Jun, Tu Haili. Problems and countermeasures for sustainable development of China' s uranium mining industry. *Science and Technology Square*, 2016, (8): 138-141.

[7] Zhang Xinwei, Wu Qiaosheng, Li Jiangfeng, et al. China' s uranium supply security and influencing factors. *China Mining*, 2014, 23(11): 149-151.

[8] Jiang Wei, Gao Weidong. China' s nuclear power development and uranium resource security under low-carbon pressure. *Resources and Environment in the Yangtze Basin*, 2011, 20(8): 938-943.

[9] Tang Chao, Shao Longyi, Chen Wanli. Analysis of China' s uranium resource security. *China Mining*, 2017, 26(5): 1-6.

[10] Chen Guanju. Research on China-Central Asia resource cooperation models. *Technology Economics and Management Research*, 2015, (6): 80-84.

[11] UN Comtrade. Extract Data. [2016-12-25]. <https://comtrade.un.org/data>.

[12] Global Legal Insights. *Energy 2017, 5th Edition -Uzbekistan*. [2016-10-12]. <https://www.globallegalinsights.com/practice-areas/energy/global-legal-insights-energy-5th-ed./uzbekistan#chaptercontent1>.

[13] Huang Wenbin. World nuclear power situation and uranium resources. *China Mining News*, 2017-06-19.

---

### Author Biographies

**Mao Hanying** is a professor at the Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences (CAS), an academician of the International Eurasian Academy of Sciences, and group leader of the Regional and Urban Design and Planning Research Center. He formerly served as Director of the Department of Economic Geography at the CAS Institute of Geography, Director of the Human Geography Specialized Committee of the Geographical Society of China, Vice President of the China Regional Science

Association, and Associate Editor-in-Chief of *Journal of Geographical Sciences*. His research focuses on regional development, regional planning, and world geography. He has led over 30 national and provincial/ministerial research projects, published 12 academic works (including co-authored volumes), and authored more than 200 academic papers. His research has received one second-prize CAS Natural Science Award (1989), two second-prize CAS Science and Technology Progress Awards (1995, 1999), three first-prize and two second-prize provincial/ministerial science and technology progress awards. In 1992, he received the State Council Special Government Allowance; in 2009, the CAS Outstanding Scientific and Technological Achievement Award; and in 2017, the China Geographical Science Achievement Award. E-mail: maohy@igsnrr.ac.cn

\*Corresponding author

*Note: Figure translations are in progress. See original paper for figures.*

*Source: ChinaXiv – Machine translation. Verify with original.*