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Analysis on the Current Situation and Trend of Nuclear Energy Development

Jing CHEN[1] and Wanlun LI
National Geological Library of China, Beijing, China

Abstract. Uranium is not only an important strategic resource for national development, but also an important global energy raw material. About 98% of natural uranium is sold to the nuclear power generation market every year, and the sales volume of nuclear power market in 2020 is 64832tU. This paper analyzes the current situation of uranium resources in the world from the aspects of uranium resource reserves and production output, and discusses the nuclear energy policy and development trend of some countries. Under "Dual Carbon" goals, countries all over the world are actively seeking alternatives to green energy and new energy. More use of nuclear energy is needed and used as a backup energy for renewable energy power plants.

Keywords. Nuclear energy policy, uranium resources, "Dual Carbon" goals

1. Current situation of World Uranium Resources

1.1. Uranium Resource Reserves

The distribution of global uranium resources is extremely uneven, mainly concentrated in 12 countries such as Australia, Kazakhstan, Canada, Russia, Namibia, South Africa, Brazil, Niger, China, Mongolia, Uzbekistan and Ukraine. The uranium resource reserves of these 12 countries account for about 91% of the world's uranium resource reserves. According to the data, in January 2019, the total amount of uranium resources identified worldwide (< $130/kg) was 6.1478 million tU, an increase of 0.1% over 2017 (Table 1) [1].

1.2. Uranium Resource Output

In terms of output, due to the continuous low price of natural uranium, production reduction has become the main tone of current natural uranium production enterprises, resulting in the continuous decline of the total output of natural uranium after reaching a new high of 63200 tU in 2016. By 2020, the global natural uranium output was 47700 tons, a year-on-year decrease of 12.8%. The output in 2020 can meet about 74% of the annual uranium demand of the world's nuclear power industry.

In 2020, there are 15 natural uranium producing countries in the world. Kazakhstan, the largest producer, produces 19500 tons of uranium, accounting for

[1] Corresponding Author, Jing CHEN, National Geological Library of China, Beijing, China; Email: 99102930@qq.com.

about 40.9% of the total output of the ball. The total output of Kazakhstan, Australia and Namibia accounts for about 65.1% of the total global output (Figure 1). Among the 15 uranium producing countries, the output of 8 countries decreased year-on-year. The four countries with the largest decline were the United States, Canada, South Africa and Kazakhstan, with a decline of 89.7%, 44%, 27.7% and 14.6% respectively.

Table 1. Uranium resources/production by country in 2019/2020 (tonnes U).

Country	Resources 2019	Percentage of world	Production 2020	Production capability to 2040
Australia	1,692,700	28%	6230	10500^
Kazakhstan	906,800	15%	19477	5000
Canada	564,900	9%	3885	18850
Russia	486,000	8%	2846	1500^
Namibia	448,300	7%	5413	9800
South Africa	320,900	5%	250	1800
Brazil	276,800	5%	15	1600
Niger	276,400	4%	2991	6800
China	248,900	4%	1885	2000
Mongolia	143,500	2%	0*	800
Uzbekistan	132,300	2%	3500	2000
Ukraine	108,700	2%	744	2000
Botswana	87,200	1%	-	1440
Tanzania	58,200	1%	-	3000
Jordan	52,500	1%	-	-
USA	47,900	1%	6	2000
Other	295,800	5%		
World total	6,147,800		47731	

Note: Identified resources recoverable (reasonably assured resources plus inferred resources), to $130/kg U, 1/1/19, from OECD NEA & IAEA, Uranium 2020: Resources, Production and Demand ('Red Book').
Production capability of existing, committed, planned and prospective centres supported by RAR and inferred resources recoverable at< $130/kg U.

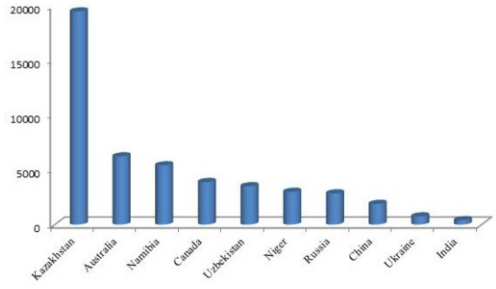

Figure 1. Top 10 countries of Uranium production in 2020 (tU).

During the 1990s the uranium production industry was consolidated by takeovers, mergers and closures, but this has diversified again with Kazakhstan's multinational ownership structure. Over half of uranium mine production is from state-owned mining companies. In 2020, the top 10 companies by production contributed over 85% of the world's uranium production (Figure 2) [2]. The top four natural uranium producers in the world are Kazakhstan national Atomic Energy Industry Corporation, France Oano company, Russia No. 1 uranium industry company and China Guangdong Nuclear Power Group [3]. The total output of the four major producers accounts for about 48% of the world's total output

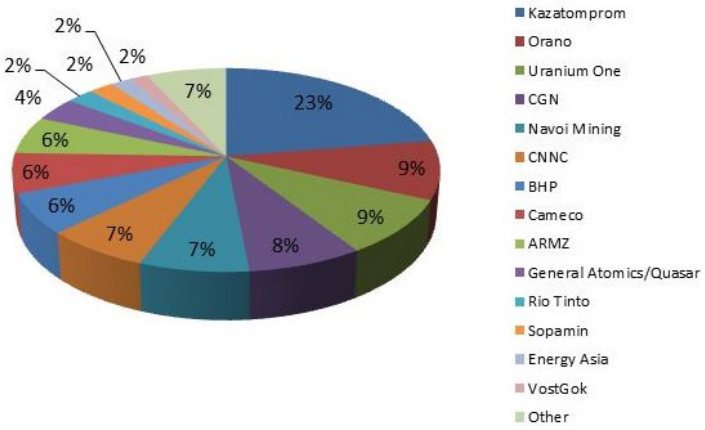

Figure 2. Top 10 companies by production in 2020.

1.3. Output of Major Mines in the World

In 2020, the total output of the world's top 10 uranium mines will exceed 24000 tons of uranium, accounting for 51% of the world's total output. Among the 10 uranium mines, four of them are located in Kazakhstan, two in Namibia, two in Australia, on in Canada and 1 in Niger. The two largest uranium mines in 2020, namely cigar lake and lake mountain, are located in Canada and Namibia respectively. The nuclear energy policies of these countries will affect the development of mines.

2. Nuclear Energy Policies of Major Countries in the World

Under "Dual Carbon" goals, countries all over the world are actively seeking alternatives to green energy and new energy. In December 2019, during the 25th conference of the parties to the United Nations Framework Convention on climate change (cop25), director general Rafael of the International Atomic Energy Agency (IAEA) said that in order to ensure the successful global transformation to clean energy, more use of nuclear energy is needed and used as a backup energy for renewable energy power plants such as solar energy and wind energy. At this stage, although nuclear energy is an important part of the world's energy composition, it is not dominant. Different countries have different attitudes and plans for the development of nuclear power (Table 2). For example, the United States, Canada, China, Russia, India,

Argentina, Brazil, Egypt, Finland, Hungary, Poland, Saudi Arabia, the United Kingdom and Uzbekistan are optimistic about the development of nuclear energy. However, many developed economies, such as France, Germany, Spain, Belgium and Switzerland, plan to gradually reduce the share of nuclear power or insist on eliminating nuclear power.

Table 2. Nuclear energy policies of various countries.

Country	Plan/policy	Main content
Ukraine	2017 New Energy Strategy	In the future, nuclear energy will still be an important part of Ukraine's energy structure, and the share of nuclear power generation in the country's total power generation will remain at about 50% by 2035.
Russia	2014 National Outline of "Development of Nuclear Industry Complex" in the Russian Federation 2018 Draft of Russia's Nuclear Energy Development Strategy before 2050 and Its Prospect Plan for 2100	The plan includes the construction of small nuclear power plants, the establishment of a waste free energy technology platform based on closed fuel cycle technology, the development of nuclear technology market and the development of new nuclear fuels. The construction of ritm-200 small reactor is planned to start in 2024 It is expected to expand its deployent and stop operating pressurized water reactors after 2040. Increase the proportion of nuclear power in Russia's energy structure to 25% by 2045 [4]. The Russian federal government will allocate about 100 billion rubles (US $1.3 billion) for the new nuclear energy development plan
EU	2021 EU sustainable finance Classification Act 2022 Draft of Research agenda for sustainable nuclear energy strategy Green Growth Energy Transformation Law	The priorities of future research and development in the field of nuclear energy in Europe are put forward.
France	Multi Year Energy Planning	In 2035, the proportion of nuclear power generation will be reduced to 50%. Maintain or gradually reduce the proportion of nuclear power plants in the national power structure.
UK	Ten Point Green Industrial Revolution Plan Net Zero Strategy: Green Reconstruction Energy White Paper	Nuclear power is an indispensable and important low-carbon power. Build a commercially viable nuclear fusion power station by 2040. The role of nuclear energy in fulfilling Britain's climate neutrality commitment in 2050 was emphasized.
Canada	2018 SMR Road Map 2020 SMR Action Plan	In March 2021, the Canadian government announced that it would provide $56 million to moltex energy for the development of SMR in the Atlantic region of Canada [5].
US	2018 Nuclear Energy Innovation Capability Act 2019 Nuclear Energy Innovation and Modernization Act 2020 Nuclear Leadership Act, Reshaping the Competitive Advantage of American Nuclear Energy: Ensuring American National Security Strategy, ZCAP, ARDP 2021 The Future of American Power Industry" Infrastructure Investment and Employment Act	The development of nuclear energy is the key support object of all US governments The US nuclear energy export policy has changed from strict prevention and adherence to nuclear non-proliferation to industrial cooperation with allied countries. Provide initial funding totaling $160 million to support the construction of two demonstration advanced reactors that can be put into operation in five to seven years. Pay more attention to the development of advanced nuclear energy and small-micro reactors; The future (zero carbon) power system technology path is listed, and micro reactor and small reactor are the key technology directions [6]. The U.S. Department of energy launched a $6 billion civil nuclear credit program [7].
Japan	2017 Basic Viewpoint of Nuclear Energy Utilization in Japan Basic Energy Plan Green Growth Strategy	Despite the impact of the Fukushima nuclear accident, Japan still takes nuclear energy as an important choice to achieve its decarbonization goal. By 2030, the proportion of nuclear power will be reduced to 20%-22%, and new policies for nuclear power development should be formulated. It is

Country	Plan/policy	Main content
		emphasized that nuclear energy is an important choice to achieve the goal of decarbonization. On the premise of restoring social trust and ensuring safety, promote the development of nuclear power. Japan's Kyoto fusion engineering company plans to build Japan's first pilot plant for power generation through nuclear fusion and put the plant into operation in the next five years [4].
India		21 new nuclear power plants will be built by 2030 [8].

The development of nuclear energy has always been the key support object of all US governments. The United States is currently the country with the largest nuclear power generation in the world, with 93 nuclear reactors, accounting for 24% of the total global nuclear power generation, and nuclear power accounts for more than 50% of the clean electricity in the United States. Nuclear energy is the largest contributor to low-carbon electricity production in Europe. In 2020, the nuclear power generation capacity was 688twh, a year-on-year decrease of 13%, but the proportion reached 25.23%, which is still the largest power generation variety. 13 of the 27 EU countries have nuclear power plants and 2 have operated nuclear power plants. The EU takes nuclear energy as part of its carbon emission reduction plan and hopes that Member States will use nuclear energy to achieve carbon neutrality by 2050. As a major energy exporter, Russia's nuclear energy export has always been Russia's national strategy, which has never stopped after the Fukushima nuclear accident. Its nuclear energy technology, including third generation reactor (VVER), small modular reactor (SMR) and floating reactor, is at the world leading level.

The "30/60" goal has created a new period of policy opportunities for the development of nuclear power. The 2021 government work report clearly stated that "actively and orderly develop nuclear power on the premise of ensuring safety". The functional orientation of nuclear power will gradually evolve from a strategic small amount of supplement to strong support for power system security, low-carbon clean power supply and multi energy complementary and comprehensive utilization. In 2021, the demand for natural uranium will exceed 10000 t, and it is estimated that the demand for natural uranium will reach 37000 Tu in 2060. According to the medium- and long-term development plan of nuclear power (2005-2020), the utilization rate of uranium resources in China will be increased by 60 times.

3. Nuclear Energy Policies of Major Countries in the World

Due to the sharp decline of uranium production in recent years and the impact of the novel coronavirus epidemic, the uranium market is depressed. The upcoming challenges may be related to the limited investment capacity, which will promote the industry to further optimize its activities. There will be innovation and development in theory, technology and policy. The new generation of uranium exploration technology is mainly marked by deep exploration, intelligence, greening and integration. The future development direction of nuclear power will be to give full play to the comprehensive energy role of nuclear power, optimize its characteristics, form effective cooperation and complementarity with other energy sources, gradually miniaturize and reduce costs. To achieve the above objectives, the government needs to effectively regulate nuclear energy, realize the safe deployment and utilization of

nuclear energy, and protect human beings and the environment from the potential harmful effects of ionizing radiation, so as to enhance the confidence of people and investors. At the same time, a strong policy environment needs to be created to create conditions for wider deployment, including promoting increased investment in nuclear energy. In addition, we should promote the research and wide application of safer nuclear energy technologies, and adopt a science led and technology neutral approach in energy policy and financing to promote sustainable cooperation between nuclear energy and renewable energy [9].

4. Conclusion

Under "Dual Carbon" goals, countries all over the world are actively seeking alternatives to green energy and new energy. In order to ensure the successful global transformation to clean energy, more use of nuclear energy is needed and used as a backup energy for renewable energy power plants such as solar energy and wind energy. The future development direction of nuclear power will be to give full play to the comprehensive energy role of nuclear power, optimize its characteristics, form effective cooperation and complementarity with other energy sources, gradually miniaturize and reduce costs. The United States, Canada, China, Russia, India, Argentina, Brazil, Egypt, Finland, Hungary, Poland, Saudi Arabia, the United Kingdom and Uzbekistan are optimistic about the development of nuclear energy.

Acknowledgements

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References

[1] Uranium2022: Resources Production and Demand.
[2] https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/world-uranium-mining-production.aspx
[3] Current situation of global natural uranium market and prediction and analysis of competition pattern in 2022. https://www.askci.com/news/chanye/20220419/1002541828680.shtml
[4] Russia: 100billion rubles will be allocated for the new nuclear energy development plan. Energy Conservation & Environmental Protection. 2022,(02):8.
[5] Tian HF. Current situation and trend of global nuclear energy development. World Knowledge. 2022;(04).
[6] Rong J, Liu Z. Development and Prospect of advanced nuclear energy technology. Atomic Energy Science and Technology. 2020,54(09):1638-1643.
[7] Wang L. Motivation Analysis of U.S.-India civil Nuclear Agreement. Shanghai International Studies University. 2021.
[8] Teng LL. Research on the nuclear policy of the United States towards India (2009-2020) [D]. Shanghai Normal University. 2022.
[9] Zhang JD, Li ZY, Su XB, Tan YH. Development strategy of nuclear energy mineral resources. Chinese Engineering Science. 2019;21(01):113-118.