Uranium Raw Material for the Nuclear Fuel Cycle: Innovation for Sustaining Future Resources and Production (URAM-2023)

Proceedings of an International Symposium
Vienna, Austria, 8–12 May 2023

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International Atomic Energy Agency

URANIUM RAW MATERIAL FOR THE NUCLEAR FUEL CYCLE: INNOVATION FOR SUSTAINING FUTURE RESOURCES AND PRODUCTION (URAM-2023)

The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world".

PROCEEDINGS SERIES

URANIUM RAW MATERIAL FOR THE NUCLEAR FUEL CYCLE: INNOVATION FOR SUSTAINING FUTURE RESOURCES AND PRODUCTION (URAM-2023)

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ORGANIZED BY THE
INTERNATIONAL ATOMIC ENERGY AGENCY
IN COOPERATION WITH THE
WORLD NUCLEAR ASSOCIATION
AND HELD IN VIENNA, 8–12 MAY 2023

INTERNATIONAL ATOMIC ENERGY AGENCY
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FOREWORD

In 2000, 2005, 2009, 2014 and 2018, the IAEA held major international symposia on uranium production and raw materials for the nuclear fuel cycle to discuss all aspects of uranium raw materials, with an emphasis on ensuring the long term sustainability of nuclear power programmes. In response to a challenging and evolving economic environment, the industry is currently seeking new and innovative ways to improve efficiencies in producing uranium.

As a result of sustained low uranium prices for more than a decade, uranium production has been decreasing in recent years, and at the same time, there has been an overall decrease in uranium exploration activity. With the decrease in primary uranium supply, the gap in demand has increasingly been met by secondary uranium supplies. However, with the decreasing availability of secondary uranium supplies and the exhaustion of primary uranium supply from current mines, the uranium resource base and production need to be further extended to meet uranium demand. Based on national policies for clean energy and projected growth in demand for electricity, there is an expectation of nuclear power growth worldwide, leading to an increase in uranium demand in both the near term and the medium term. The long term sustainability of nuclear power will depend on, among several factors, an adequate supply of uranium resources that can be delivered to the marketplace at competitive prices. Owing to long lead times from uranium deposit discovery to production (i.e. 10–20 years on average), investment in uranium exploration and mining is required now.

The International Symposium on Uranium Raw Material for the Nuclear Fuel Cycle: Innovation for Sustaining Future Resources and Production was held in Vienna 8–12 May 2023. The purpose of the symposium was to analyse supply and demand scenarios and to present and discuss the latest developments and innovations in uranium geology, exploration, mining, processing and site decommissioning to ensure a sustainable supply of uranium for use as nuclear fuel.

This publication provides a summary of the symposium including the opening addresses; the essay contest for students and early career professionals; summaries of ten tracks from the technical sessions and the two panel sessions; the closing addresses; and lists of the conference secretariat and programme committee and of the papers and posters. The accompanying supplementary files, available on-line, include the symposium programme, individual technical abstracts and papers (orals and posters), and the four winning essays from the contest for students and early career professionals.

The IAEA would like to express its appreciation to the members of the symposium programme committee and the symposium secretariat for convening and organizing the symposium. The IAEA officers responsible for this publication were A. Hanly and M. Mihalasky of the Division of Nuclear Fuel Cycle and Waste Technology.

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1. SUMMARY

The International Symposium on Uranium Raw Material for the Nuclear Fuel Cycle (URAM–2023) was held in Vienna on 8–12 May 2023. The purpose of the symposium was to analyse supply–demand scenarios and to present as well as discuss the latest developments and innovations in uranium geology, exploration, mining, processing, and site decommissioning to ensure a sustainable supply of uranium for use as nuclear fuel. The emphasis was on ensuring the long-term sustainability of global nuclear power programmes.

Plenary opening sessions were held on Monday. Technical sessions, held as two parallel streams that included 10 topical tracks, took place on Tuesday, Wednesday, and Thursday, with poster sessions on Tuesday and Wednesday afternoon. Two panel discussion sessions were held on Thursday afternoon, the first focussing on sustainability of supply of nuclear fuel, and the second on women in uranium exploration and mining. Closing sessions were held on Friday morning.

A total of 258 participants and 121 observers, drawn from 63 countries and 3 international organizations were recorded as attending. About 137 attended the symposium in-person. A total of approximately 170 abstracts and extended abstracts from 39 countries were reviewed, with 134 accepted and presented as 85 technical session oral papers and 49 posters. The opening and closing plenary session consisted of 17 keynote presentations on policy and global uranium supply and demand. In addition, new to this year's URAM Symposium series, an essay competition for students and early career professionals was held, attracting 24 essays, from which the top 4 were selected for funding to attend the symposium and to deliver presentations at the opening plenary session.

2. OPENING SESSION

2.1. IAEA DIRECTOR GENERAL OPENING REMARKS

As prepared for delivery.

R. M. Grossi
Director General
International Atomic Energy Agency,
Vienna, Austria

Chairperson Hall, colleagues, ladies and gentlemen,

Welcome to the International Symposium on Uranium Raw Material for the Nuclear Fuel Cycle – URAM 2023, the IAEA's flagship event focusing on issues associated with the uranium production cycle.

The challenge of meeting the United Nations' Sustainable Development Goals and the targets set out in the Paris Agreement will largely depend on one factor: energy. In the coming decades we will need more energy, but specifically, we will need more clean energy.

All low-carbon energy technologies will have an important role to play.

Today, there are 413 nuclear power reactors operated in 32 countries and generating 10% of the world's electricity and one quarter of its low-carbon electricity generation. To fuel these

reactors requires about 60,100 tonnes of uranium annually. Based on the 2022 edition of the Red Book publication it is projected that by 2040 this demand could be as high as 108,200 tonnes of uranium per year. This would require a near doubling of global uranium mining and processing.

To shift to a more sustainable energy path, decarbonizing not only the electricity grid, but also, hydrogen production, industry, heat production, desalination and transport, the world will need to more than double nuclear power capacity by 2050. And this will require advanced reactors, including small modular reactors (SMRs).

There is promising work on new generations of nuclear reactors that require less uranium, including SMRs.

Some countries are interested in thorium fuel cycle. But the thorium cycle is still at the experimental stage and there are many stages to go before commercialization, which is possibly still decades away. That means we will need to keep the current and future nuclear fleets fuelled with uranium for as long as possible.

You are here today to:

–Better understand the adequacy of uranium supply to meet future demand;

–Discuss the latest research, technologies and innovations related to the development of new uranium sources;

–Examine technical, economic, environmental, safety and social aspects of exploration for and mining of uranium.

While it is estimated the world will have enough uranium supply for decades, we cannot be complacent. Many factors affect the uranium supply/demand relationships. These include national policies for Nuclear Power Plants; timing of new builds; lifetime extension of current NPPs and the adoption of open/closed nuclear fuel cycles. Supply will be determined by the volume of uranium exploration and the timing of new uranium projects, which increasingly are becoming national priorities.

We need to make sure uranium is mined, produced and managed efficiently and sustainably so that it can fuel both today and tomorrow's reactors. This requires adequate services, expertise and innovative modern technologies.

Effective regulation, sound environmental management, training and education must be there to minimize the potential negative impacts of uranium mining and production, and to contribute to the public's acceptance of the global nuclear industry in general.

As you know, the main environmental challenges with uranium mining and processing are waste rock, tailings and the impact on water quality by effluents produced during mining and processing. There are promising projects – like NexGen's Rook 1 project in Canada – that seek to address these negative externalities. In fact, NexGen's Rook 1 project will be one of the case studies of this conference.

For countries that decide to do engage in uranium production, our role is to assist them do it safely, securely and sustainably.

Although the uranium production cycle is a less well-known focus of the Agency's work, our support to Member States covers all aspects of the cycle:

We produce relevant publications with best practice guidelines for various stages of the process such as the 2023 IAEA Nuclear Energy Series publication *Milestones in the Development of National Infrastructure for the Uranium Production Cycle*.

We offer capacity building through technical training and knowledge development, through relevant IAEA publications, coordinated research projects and also workshops, training courses, expert missions, and fellowships and scientific visits through the IAEA Technical Cooperation Programme.

We produce databases – including a unique and interactive map of world uranium deposits, which supports Member States and their Geological Surveys to better understand uranium geology, mineralogy and potential targets for uranium exploration. This map is one of most downloaded IAEA publications.

The IAEA offers technical advice on various aspects of the uranium production cycle, from exploration, mining and processing technology selection, to construction, operation and closure.

The Agency supports Member States in developing remediation plans for uranium mines that are not operating anymore.

Through our review missions, we help countries ensure safe and secure handling of uranium, through its entire life cycle.

Let me conclude by urging you to make full use of the opportunities offered by the IAEA, today at this event and when you return home. I wish you a fruitful time of learning, exchanging ideas and developing new ones. And I look forward to hearing the outcome of your work. Thank you.

2.2. OPENING REMARKS BY SYMPOSIUM SCIENTIFIC SECRETARY

Verbatim as delivered.

B. Moldovan
Technical Lead Uranium Production and Resources
International Atomic Energy Agency
Vienna, Austria

Dear Colleagues, DG Grossi, Chairperson Hall, Ladies and Gentlemen, good morning.

Welcome to the International Symposium on Uranium Raw Material for the Nuclear Fuel Cycle – URAM 2023, the IAEA's premier event focusing on various issues associated with the uranium production cycle. I am very pleased to welcome all of you. It is once again an exciting time in our industry, and I look forward to an engaging an informative week ahead. This Symposium allows for the unique opportunity for industry and IAEA Member States to network and learn about the good practices and lessons learned.

Ladies and gentlemen,

Globally, in the coming decades we will need more energy, and countries have an opportunity to develop policies and strategies to ensure the availability of clean energy sources. All low-carbon energy technologies will have an important role to play, however, in order to obtain reliable, clean baseload power, we will need more nuclear power.

Uranium is currently the fuel source for nuclear power reactors. There is promising work on new generations of nuclear power reactors that require less uranium, including small, medium sized or modular reactors. Some countries are interested in thorium fuel cycle. But until we get there, we will need to ensure adequate uranium as fuel to keep the current and future fleet of nuclear reactors operating for decades to come.

This week, we have the great opportunity this week to share our experiences on current activities in the industry and also present on innovation to ensure a sustainable supply of nuclear fuel for the current and future fleet of nuclear reactors. Even though the uranium industry is mature there remains an opportunity for new innovation across all phases of the uranium production cycle including exploration, mine and processing facility engineering and operation; and also through decommissioning and remediation.

Efficient and responsible uranium mining is an important aspect of this effort. While it is estimated that the world will have enough uranium supply for decades, we have to make sure that it is indeed mined, produced and managed sustainably to avoid a shortfall. We need adequate services, expertise and innovative modern technologies to ensure a socially acceptable and sustainable supply of uranium raw materials to fuel both operating and future nuclear power reactors. Effective regulation, sound environmental management, training and education are required to minimize the potential impacts of uranium mining and production, and to contribute to the public's acceptance of the global nuclear industry in general.

Ladies and gentlemen,

The IAEA provides support to its 176 Member States across the nuclear fuel cycle including uranium exploration, mining, processing, refining and conversion. The IAEA also provides support to its Member States on nuclear fuel engineering including advanced technology fuels for Gen IV reactors and SMRs. Lastly, the IAEA provides support on the back end of the nuclear fuel cycle including spent fuel management, reprocessing of spent fuel and final disposal. We will hear later this afternoon in more detail on how the IAEA provides support to its Member States in the uranium production cycle through the Technical Cooperation Programme.

We have an exciting week ahead. Today in the opening session we will hear more about national policies for nuclear energy as well as demand and supply dynamics for nuclear fuel. From Tuesday to Thursday, we have the technical talks and which will be divided into two parallel sessions. On Thursday afternoon we have an engaging panel discussion with global experts. We will close the conference on Friday with presentations from industry leading producers.

Let me conclude by wishing you a fruitful time of learning, exchanging ideas and developing new ideas. I am looking forward to hearing the outcome of your work.

The IAEA remains committed to helping the world meet its greatest challenges.Thank you.

I would now like to pass the floor over to our Conference Chair, Ms Susan Hall, for her opening remarks.

2.3. OPENING REMARKS BY CHAIRPERSON OF THE SYMPOSIUM

Verbatim as delivered**.**

S. Hall
Uranium Resources Specialist
United States Geological Survey
Denver, United States of America

Good morning and welcome to URAM 2023. I have been fortunate to have been attending the URAM conferences since 2009 and with each successive meeting have been increasingly impressed by the quality of presentations, and the expert, high-level discussions among attendees. Reading through the variety and complexity of topics, and line-up of talented speakers scheduled for this week, URAM 2023 builds upon this momentum and promises to be an even better conference than the last.

I'd like to take this opportunity to thank the organizing committee for their hard work in planning this Symposium. From IAEA Mr Brett Moldovan, Ms Carmen Good, Ms Lucia Suarez-Leon, Mr Mark Mihalasky, Ms Adrienne Hanly, the conference services team, and clerks who are working madly behind the scenes to make sure AV equipment is functioning and water pitchers are filled. Members of the international uranium community including Mr Alexander Boytsov, Mr Alexandre Aubin, Mr Daniel Bellifemine, Mr Michel Cuney, Mr Nils Hanekelaus, Mr Patrick Ledru, Professor Ziying Li, Ms Gabi Schneider, Ms Aliya Akzholova, and Mr Tom Calvert virtually met with IAEA staff over the course of many months at ridiculous hours in their home time zones to provide their expertise and help to the committee. Thank you all.

Thank you, attendees, for making the time, finding funding, travelling long distances, and sharing your work with this scientific community. You have contributed almost 150 abstracts that will be presented as talks and posters throughout the week, and more than 50 extended abstracts that will be including in the conference volume. We are all very much looking forward to hearing your stories. And a special welcome to the early career professionals who were selected from so many outstanding entries to the URAM 2023 essay competition. Seasoned professionals and newcomers both – you are the meeting.

As Director Grossi reminded us, the world is on the cusp of another uptick in interest in uranium as a commodity and in nuclear power as an increasingly important source of low-carbon energy. The questions we will be considering this week are those factors that impact the projections of adequate uranium supply. The answer is complex. Influencing supply are many factors including the identification of in place resources that requires updated genetic deposit models and advanced exploration techniques to identify concealed deposits. Considerations of the technical and geopolitical vulnerabilities of permitting and operating mines are critical, as are securing funding for project development, understanding the impact of domestic government programs focused on securing national supply, evaluating volumes and sources of secondary supplies, and understanding the impacts of the recent entry of uranium holding companies into the supply chain.

Presentations and panel discussions planned for the week ahead will explore these different factors that influence supply. The goal of the sessions is to provide a venue in which you, conference attendees, can develop deeper understandings of regions where uranium supply may be found, to exchange information about the development of efficient, economic, and

environmentally sensitive extraction techniques, to develop better processing techniques and to plan programs to train workers to implement the best methods of all these aspects of uranium production. While you attend the sessions, I encourage you to ask probing questions of your colleagues, to seek them out during coffee breaks, and to begin to collaborate to answer many of these complex questions.

I hope you have a week filled with learning, revitalized enthusiasm about your work, and the development of new or deeper friendships with colleagues worldwide. Our stories and our studies are powerful and more powerful shared. We work better together. Enjoy your meeting and enjoy your week.

3. PLENARY SESSION

3.1. GLOBAL URANIUM SUPPLY AND DEMAND DYNAMICS AMID HEIGHTENED GEOPOLITICAL RISK

N.Carter
UxC, LLC
Executive Vice President, Uranium
Georgia, United States of America

The low post-Fukushima uranium prices of US$ 18/lb U_3O_8 increased by up to 183% and are now above US$ 50/lb U_3O_8. Geopolitical tensions are further supporting higher uranium prices. Nuclear power is regarded as a relatively secure method of energy production, that can be more independent from geopolitical tensions with the Russian Federation than other energy sources. Russian nuclear fuel cycle services and uranium imports have not been sanctioned yet, although the USA and the EU are considering sanctions. Utilities largely suspended new contracting with Russia. While these geopolitical tensions with an important uranium producing country continue, nuclear power is generally receiving increased approval as a potentially inexpensive, secure, and low carbon emitting energy source. In Europe energy prices have surged, and Czech Republic, Hungary, France, Poland, Romania, Slovakia, and others are accelerating the construction of new nuclear power plants that will result in an overall increase in uranium demand. In North America reactor lifetimes are planned to be extended. In addition, US government programs, namely the 2021 Infrastructure Bill, as well as the 2022 Inflation Reduction Act, are providing considerable incentives to accelerate the development of future nuclear power plants. Specifically, the development of small modular reactors is presently led by Canada but will probably see the highest use of the technology in the US. Nuclear power is no longer on the side-lines, but rather at the center of North American clean energy efforts. In Asia, China is accelerating nuclear energy production with currently 23 reactor units under construction. South Korea is planning to extend the lifetime of the current nuclear fleet with additional new builds. Japan is also planning for lifetime extensions, India is planning to increase its fleet of pressurized heavy water reactors (PHWRs), and several nuclear newcomers, such as Bangladesh, Indonesia and the Philippines, are becoming more active.

UxC offers three uranium demand projections: high demand, base demand, and low demand. Nuclear reactor requirements are forecasted to increase by 62% over the next 17 years, so that the base case shows a growth of global uranium demand of 33% from 2023 to 2040. In the near term the uranium spot market prices will continue to be affected by potential sanctions on the Russian Federation by western countries. In the long term, the increased future demand will have to be met by an increase in uranium production.

3.2. TAXONOMY, SMALL MODULAR REACTORS, AND URANIUM MARKETS

A. Florea
Directorate General for Nuclear Energy, Safety and ITER in DG ENER
European Commission, Luxembourg

The 'EU taxonomy' is a list of economic activities that are considered environmentally sustainable for investment purposes. The taxonomy is not an instrument of EU energy policy making, but an intent to provide more transparency in financial markets to private investors. Nuclear power and natural gas are presently considered to be important transitional sources towards renewable energy. With regard to nuclear power, there are presently three main activities in the EU taxonomy: (1) Upgrades of existing installations; (2) New builds using existing best available technologies; and (3) Pre-commercial stages of advanced technologies with minimal waste.

Independent of the EU taxonomy, there is considerable interest in small modular reactor (SMR) development in the EU and Europe. The Czech Republic, Estonia, France, Poland, Romania, Sweden, and the United Kingdom are all actively working on small modular reactor projects, with the first deliveries planned around 2030. The EU is supporting these efforts through its small and modular reactor pre-partnership, which aims to identify enabling conditions and constraints towards safe design, construction, and operation of small and modular reactors in Europe in the next decade and beyond, while in compliance with the EU legislative framework in general, and the Euratom legislative framework in particular.

With regard to EU uranium markets growth, and an increase in uranium demand is forecasted as a result of the recognition of nuclear power as a transitional energy source in the EU taxonomy, as well as the increased interest in small and modular reactors in the EU.

3.3. FUEL CYCLE - SECURITY OF SUPPLY

P. Costes
Senior Advisor
World Nuclear Association, United Kingdom

Nuclear power favors energy security and can contribute to producing both affordable as well as low-carbon energy. The World Nuclear Association (WNA) offers three scenarios to project future uranium demand: (1) An upper scenario; (2) A reference scenario; and (3) A lower scenario. The uranium demand is generally determined in a bottom-up approach based on the projected nuclear reactor requirements. From 2020 to 2040 an annual growth of 2.9% of nuclear generating capacity is projected in the reference scenario in the 2021 *WNA Fuel Report*. The resulting increased future uranium demand will have to be met by increased future production of uranium. In this context it is noteworthy that, in 2020, only 74% of reactor requirements were met by primary uranium production. In the long-term, exploration and development of new mines, as well as the activation of idle mines, will be required to meet the increased demand for uranium. Investment in other fuel cycle capacities, such as conversion, enrichment and fuel fabrication, will also be needed.

There are considerable regional imbalances that were highlighted. The Russian Federation plays relevant roles in uranium mining, conversion, enrichment, and fuel fabrication. Additionally, the Russian Federation also controls transport routes, such as transporting U_3O_8

from Kazakhstan through the port of St. Petersburg to consumers worldwide. The current armed conflict in Ukraine and potential sanctions on Russian nuclear fuel cycle services could require new capacities in Western countries in the mid-term.

3.4. THE OECD-NEA/IAEA URANIUM GROUP & THE 'RED BOOK'

M. Mihalasky
Uranium Resources Specialist
International Atomic Energy Agency
Vienna, Austria

The Joint OECD-NEA / IAEA Uranium Group (UG) is a long-standing collaborative association between the Nuclear Energy Agency (NEA) of the Organisation for Economic Cooperation and Development and the International Atomic Energy Agency (IAEA). It is a forum for the exchange of information, analysis, and guidance on the uranium market and its role and relationship with respect to the global nuclear fuel cycle. It provides a platform for dialogue and cooperation among governments, industry, and other stakeholders on issues related to the uranium market and the nuclear fuel cycle. Approximately 50 members from 40 countries comprise the UG, whose members are officially nominated by a government authority, and include various government officials, functionaries, policy-makers/analysts, geologists, engineers, miners, economists, fuel buyers, and other uranium professionals.

Since the mid-1960s, the NEA and IAEA have jointly prepared periodic updates (currently every two years) on world, *Uranium Resources, Production and Demand* – commonly known as the 'Red Book'. It is an essential reference work, presenting a statistical profile of the global uranium industry, including narratives and data on current and projected uranium exploration, resources, production, demand, and stocks, along with detailed country reports featuring information on mine development plans, status of environmental and social aspects of uranium mining, and national regulations and policies. The Red Book is based in large part on information provided by official government sources obtained through surveys of NEA and IAEA member countries and states.

The 2022 edition of the Red Book concludes that global uranium demand is expected to continue to increase over the next several decades, and that nuclear power plants can produce competitively priced, low-carbon baseload electricity, which will be an important component in the mix of clean and green energy. Identified recoverable uranium resources at <US$ 130/kgU (equivalent to US$ 50/lb U_3O_8) are sufficient for about 100 years (considering current demand), but for more economically minable uranium at <US$ 80/kgU (equivalent to US$ 30/lb U_3O_8, which was the approximate market spot price prior to 2021), resources are sufficient for only about 30 years. In order to meet the demand for refined uranium ready for nuclear fuel production, favourable prices will need to be further sustained (≥ US$ 50/lb U_3O_8, which is the approximate current market spot price), investment to improve exploration and develop cost-effective extraction methods will need to be made, and research and technical innovation will be required to recover uranium from low-grade deposits, such as phosphate deposits.

3.5. INNOVATION AND ACHIEVEMENTS OF URANIUM EXPLORATION AND EXPLOITATION IN CHINA

W. Cheng
President
China National Uranium Corporation
Beijing, China

The uranium exploration and mining industry in China was started in the early 1950s, and over the following 60 years, a comprehensive uranium exploration and production system was established. The first uranium ore was discovered in 1954 in South China.

Due to successful implementation of in-situ technology, since the end of the 20th century, the exploration for uranium resources has been focusing on sandstone-hosted uranium deposits in the sedimentary basins, whereas previously exploration focused on granite, volcanic rock type uranium deposits. China's uranium resources are widely distributed, but mainly concentrated in Mongolia, Jiangxi, Xinjiang, Guangdong, Hunan, Guangxi and other provinces, together which account for more than 80% of known resources. Exploration depth is shallow; mostly less than 500 metres in depth, but in recent years extending to 1000 metres. According to the latest forecast of the China National Uranium Corporation, the potential for conventional uranium resources is estimated to be 2.89 million tU, with unconventional uranium resources exceeding 2.1 million tU.

Technical and management innovation has achieved significant results and progress for both discovery and exploitation of uranium resources. The degree of uranium exploration is relatively low, and there is still extensive greenfield and brownfield areas to be explored. Over the past 20 years, a number of >10 000 tU sized uranium deposits have been discovered, and the total amount of new uranium resources is equivalent to the total amount of resources known in the previous 45 years. New mining technologies, such as using $CO_2 + O_2$ in-situ recovery technology, have been used to extract uranium from sandstone-hosted uranium deposits, and digital mining technology has increased recovery efficiency.

3.6. KAZATOMPROM: READY TO MEET THE GROWING DEMAND

A. Akzholova
Acting COO
Kazatomprom NAC
Kazakhstan

There is a growing gap between uranium supply and demand. The market is observing a significant growth in uranium demand due to various geopolitical and ecological reasons. Although some uranium producers switched to restarting idled capacity, all mine development risk is presently assumed by primary producers in a continuously unpredictable market environment. The current level of extended contractual agreements hinders significant mine development efforts.

Kazatomprom (KAP) is the largest producer of natural uranium, with priority access to one of the world's largest uranium reserve bases. In 2022, KAP accounted for 22% of total global uranium production, equalling 11 373 tU. The total uranium reserve accessible by KAP in 2022

was 312 900 tU, with additional resources (not reserves) of 464 800 tU, most of these reserves and resources occurring in the Inkai, SMCC, and Budenovskaye projects.

Most of the operating Kazakh mines can produce up to 20 years, but starting in the 2030s, KAP will experience a significant drop in production capacity. There is uncertainty around uranium supply after 2029 that cannot be resolved without guaranteed demand from utilities. Some utilities are already taking measures to improve their positions through signing longer-term contracts and boosting their strategic inventories on the existing production. But, nevertheless, the overall consensus is that there is definitely a need for new mine supplies to meet the future demand. Future exploration is clearly necessary to meet this future demand, however, there is no strong market incentive to launch new uranium production without secure contracting, which contributes to reducing both producers and utilities uncertainty.

3.7. URANIUM SUPPLY, DEMAND AND PRODUCTION IN AFRICA

G. Schneider
Executive Director
Namibian Uranium Institute
Namibia

A historical and current overview of uranium mining and uranium exploration activities in Africa was provided with a focus on Namibia. Namibia currently has two operating mines, Rössing and Husab, and in 2021, Namibia was the second largest uranium producer. The Langer Heinrich mine, which has been on care and maintenance since 2019, is scheduled to restart production as early as 2024, and the Trekkopje mine is ready to restart given the appropriate market signals. Advanced uranium projects in Namibia include Etango 8, central Erongo and Valencia. Several other exploration activities are currently in progress by Zhonghe Resources and Headspring Investments. The latter project is the first uranium project in Namibia considering in-situ recovery method for sandstone deposits.

The role of the Namibian Uranium Association and Namibian Uranium Institute was explained. Noting that the organizations support the uranium exploration, mining and export industry in Namibia through continuous development of health, environmental, and radiation safety best practices.

Other current uranium producing countries in Africa include Niger and South Africa. Past uranium production in Africa included the Democratic Republic of the Congo, Gabon, and Malawi. Exploration for uranium occurs in 34 countries in Africa. The presentation closed with mentioning how the IAEA ‘Milestones’ approach to the development of the national infrastructure for the uranium production cycle could assist African countries with the challenges that are faced in uranium exploration and mining.

3.8. ESA'S PERSPECTIVE OF NUCLEAR MARKET AND SECURITY OF SUPPLY OF NUCLEAR FUEL

D. Kozak
Euratom Supply Agency
Luxembourg

The Euratom Supply Agency's (ESA) perspective on the supply of natural uranium, conversion and enrichment, uranium price indices, and recommendations were presented. In the EU it was noted that, from 2013 to 2021, utilities were loading more fresh fuel into their reactors while buying less uranium so that it can be assumed that larger shares of the utility's inventories were used. In contrast, during 2022, EU utilities were buying more fuel than what was being loaded into reactors. Four countries (Canada, Kazakhstan, Niger and the Russian Federation) provided more than 90% of the deliveries of natural uranium to the EU in 2022.

Regarding uranium price indices, since 2019, there has been limited activity in the spot market as per the recommendations from ESA to consider long term contracts for security of supply. Ninety-eight percent of activity is in the long-term market. The multiannual price in US dollars has increased from 2020 to 2022, although the MAC-3 (weighted average over the previous three years) price indices has decreased.

EU conversion services were provided by four companies, and the contribution from EU services (Orano) increased by 10% in 2022. Enrichment services were provided by EU (Orano), approx. 60% and the Russian Federation (Tenex), approx. 30% and the remainder by non-EU suppliers. Future requirements for conversion and enrichment services in the EU are based on conservative estimates of demand (i.e. operating reactors and those reactors in the final phase of construction), and are forecasted to increase slightly until 2025, and then decline until 2040. On a contractual basis, most needs will be met until around 2025 to 2026, after which time new contracts will be required.

ESA's viewpoint on conversion capacity is that, globally, conversion capacity will need to be increased as early as 2025, however the EU has enough capacity for its own needs. For enrichment, in the world market, the forecast indicates that there will be a gap as early as 2026 or 2027, and currently in the west it is already perceived as an issue. On the contrary, for the EU, the capacity exceeds the forecasted demand.

The presentation concluded with ESA's recommendations on various aspects of the market, including EU and national policies; risk assessment, response and monitoring; supply of materials and services (including uranium mining); using secondary sources of supply (i.e. reprocessing of uranium); fuel fabrication; stocks and inventories of uranic materials; tendering and contractual aspects; transport (i.e. alternative routes, rule harmonization); and medical isotopes (clear policies on research reactor fuels, stable and radiogenic isotopes).

3.9. SUPPORTING MEMBER STATES IN THE FRONT END OF THE NUCLEAR FUEL CYCLE – TECHNICAL COOPERATION AND NUCLEAR FUEL CYCLE AND MATERIALS SECTION MILESTONES APPROACH

J. Romero Bastante
Project Management Officer
International Atomic Energy Agency
Vienna, Austria

A. Hanly
Uranium Production Specialist
International Atomic Energy Agency
Vienna, Austria

Mr Romero Bastante provided an overview of the programmes in the IAEA Department of Technical Cooperation (TC), including their main purpose, why and how the TC programmes are implemented, and for whom the services are suitable. The main features of each type of programme were explained, followed by a summary of the projects that are being supported by TC in the uranium production cycle. Currently, the TC programme supports one inter-regional project with approximately 52 Member States, one regional project in Africa with approximately 30 Member States, and 14 national projects in 7 Member States. The remainder of the presentation focused on the features and activities of the inter-regional project, which involves most of the Member States that are currently engaged in uranium production cycle activities.

Ms Hanly subsequently provided information regarding the practical implementation and support of uranium production cycle (UPC) activities to Member States through the approach described in the recently published NE Series document *Milestones in the Development of National Infrastructure for the Uranium Production Cycle*. Development of national infrastructure in the UPC is a complex task, and as such, the task has been broken down into four main milestones to support Member States in a systematic and manageable way. For each milestone, there are sixteen aspects that should be considered and the details on how each of these aspects can be achieved or demonstrated is outlined in the recently published NE Series document. As part of the milestones approach, the Agency provides peer review services through an Integrated Uranium Production Cycle Review (IUPCR) mission. These missions can be requested to cover all phases of the UPC, from exploration to mining, through to decommissioning. Two new technical documents are under preparation to support the implementation of IUPCR missions, and IAEA e-learning modules are also under preparation to support UPC activities including the IUPCR missions.

4. ESSAY COMPETITION FOR STUDENTS AND EARLY CAREER PROFESSIONALS

4.1. ESSAY COMPETITION AWARD CEREMONY AND REMARKS

Verbatim as delivered.

B. Moldovan
Technical Lead Uranium Production and Resources
International Atomic Energy Agency
Vienna, Austria

This year we had the opportunity to host an essay competition for students and early career professionals.

To be considered for selection in this young professionals competition, submitted essays had to focus on one or more of the following questions:

- The key considerations for the future of the uranium production cycle the role of nuclear power generation in the years to come?
- How can the industry, regulatory bodies, and international organizations build trust and demonstrate to stakeholders that the uranium production cycle is safer now than ever before?
- What role does innovation play to minimize the impact of uranium mining and production?
- What are the greatest impediments to increasing awareness and interest amongst the youth about opportunities in uranium raw material industries, and what can be done to support the development of the next generation of experts/professionals?

We received a total of 24 essays and we selected the top 4 essays. Today we have the pleasure of recognizing these four young professionals and the privilege to have Director General Grossi present the award certificates.

Director General Grossi, may I kindly request that you join Mr. Clement Hill at the front of the room. We will then announce the winners one by one and they will be able to come up and receive their award certificate;

- Ms Fatou Gitteh from The Gambia.
- Ms Dwi Rahayu from Indonesia.
- Mr Daniyar Ashimov from Kazakhstan.
- Mr Cebastien Guembou Shouop from Cameroon.

Please join me in congratulating these esteemed four young professionals. We will have the opportunity later today to hear their essay presentations.

4.2. SUMMARY OF ESSAY PRESENTATIONS

4.2.1. Awareness and interest among youths in the uranium raw materials industry - challenges and proposed solutions

F. Gitteh
The Gambia

Ms. Gitteh conducted her own survey on youth perception on uranium raw material industry and presented a proposal for youth and industry incentivization based on salaries, scholarships, training/mentorship, and recognition. Ms. Gitteh's essay is available in the supplementary files of these proceedings.

4.2.2. Addressing the future of uranium exploration, mining, and production: the global concern and perspectives

C.G. Guembou Shouop
Cameroon

Mr. Guembou Shouop described how the involvement of young generation societies in uranium-related topics and the transfer of knowledge between different generations is fundamental for sustaining human resources in uranium technology. Mr. Guembou Shouop's essay is available in the supplementary files of these proceedings.

4.2.3. Youth and uranium: challenges and concrete solutions

D. Rahayu
Indonesia

Ms. Rahayu presented ideas on how to attract the young generation into the uranium industry and how perception among young people, especially millennials, can be changed. Ms. Rahayu's essay is available in the supplementary files of these proceedings.

4.2.4. Future of uranium mining

D. Ashimov
Kazakhstan

Mr. Ashimov shared his personal story of an exceptional scholarship programme of the Republic of Kazakhstan that lead him to the uranium industry. His presentation also proposed innovations in blockchain technology to depict how the young generation can access data that promotes the nuclear energy industry as a whole. Mr. Ashimov's essay is available in the supplementary files of these proceedings.

5. TECHNICAL SESSIONS

5.1. NUCLEAR POWER AND ENERGY MARKETS

Three oral presentations and 3 posters were presented in this track (6 total). This included one presentation that was made in the opening session on uranium activities in Namibia and the African region, and one presentation in the closing session on the history, status and outlook of the uranium industry, which have been summarized in the proceedings under those sections. One oral presentation was made on uranium exploration, resources, demand and supply in Argentina. Three posters were presented on: (1) Planning of uranium production for the nuclear fuel cycle in Uganda; (2) Knowledge management in the context of growing interests on uranium resources and the introduction of nuclear power in Africa; and (3) An estimation of materials in the nuclear fuel cycle using IAEA information and databases.

5.2. APPLIED GEOLOGY AND GEOMETALLURGY OF URANIUM AND ASSOCIATED METALS

The track consisted of 17 oral and 6 poster presentations (23 total). Contributions included investigations of hydrothermal, magmatic, volcanic, sandstone, unconformity, and phosphate-related deposit types, which are classified and characterized using various geochemical and trace element, geochronologic, geometallurgical, structural and tectonic, metallogenic, and other database and statistical analysis methods. The scales of examination range from field samples, to ore bodies and deposits, to mineral districts, orefields, and metallogenic belts, which are located in craton/shield areas, basins, plateaus, and shear zones. The presentations and discussions cover regions in Brazil, Cameroon, Canada, China, India, Jordan, Malaysia, Ukraine, and the United States.

5.3. ADVANCES IN URANIUM AND THORIUM EXPLORATION

One poster and 18 papers were presented in this track (19 total). Presentations included studies on uranium mineralization and potential for uranium mineralization in Peru and Brazil and uranium, thorium and rare earth elements in Canada and the Ukraine. One paper was based on data derived from the IAEA's uranium deposits database (UDEPO). Two papers covered aspects of uranium exploration and characterization of unconformity-type uranium deposits in the Athabasca Basin, Canada. Two papers focussed on exploration for uranium deposits in Saskatchewan, but outside the Athabasca Basin, Canada. Three papers focussed on exploration of sandstone deposits including: (1) A systematic process for exploration based on a technical document in draft by the IAEA; (2) Utilization of seismic technology for prospecting for uranium in China; and (3) A new type of uranium deposit for Namibia. A poster presented information on analysis of uranium including a differential technique for laser and LED fluorimetry. One paper was presented on the distribution of thorium deposits and their characteristics in China. Four papers described a number of assessment tools for uranium mineralization including: (1) Trace element mapping by laser ablation inductively coupled plasma spectroscopy of uraninite; (2) Utilization of artificial intelligence to detect uranium anomalies in geophysical data in Brazil; (3) Efficient workflow for predicting various logging variables using simple machine-learning programs for unconformity-type uranium deposits in Canada; and (4) Using deep learning modelling of rare earth elements as a proxy for uranium prospectivity in carbonatites in Kenya. One paper provided an overview on a methodology for assessing global uranium resources. Orano provided an overview of their activities in innovation in multiple areas such as exploration, mine operations, ore processing as well as health, safety and environment.

5.4. PROJECT MANAGEMENT AND EVALUATIONS OF URANIUM AND THORIUM PROJECTS

The track consisted of 2 oral presentations and 1 poster (3 total). The papers discussed the roles of the Nuclear Materials Authority in Egypt as well as the Department of Energy Office of Legacy Management of the United States of America in uranium and thorium exploration projects in the respective countries. Both institutions provide guidance for uranium and thorium exploration that allow entities of these Member States to carry out their geological exploration efforts. One poster was presented on Kazatomprom's experience in accounting and control of natural uranium

5.5. UNDERGROUND AND OPEN PIT URANIUM MINING, MILLING AND PROCESSING

The track consisted of 6 oral presentations and 2 posters (8 total) that discussed uranium mining, milling and processing in Canada, China, Egypt, India, Jordan, Namibia, and Niger. The presentations and posters focussed on improvements and maximization of uranium extraction and recovery through the application of analysis and modelling of mining, milling and processing data, as well as evaluation of geologic and metallogenic setting. The uranium mining, milling and processing operations that were discussed are operations conducted on industrial scale for commercial uranium production.

5.6. URANIUM PRODUCTION BY THE IN-SITU LEACHING (ISL)/ IN SITU RECOVERY (ISR) PROCESS

Four oral presentations were included in this track. The possibility of extracting associated metals, including gold, scandium, germanium and other metals, from uranium-bearing ores in Kazakhstan utilizing the in-situ method was presented. Another paper on in-situ recovery was presented for the KJET Deposit, Northwest China, where it was demonstrated that in-situ bioleaching was much more efficient than acid leaching. Orano presented a review of data from its historical in-situ mines in Texas and Wyoming, current operations in Kazakhstan, and ongoing pilot test sites in Mongolia and Uzbekistan, including the lessons that were learned from these various geological and environmental conditions. Another paper presented information on scientific, technological, and innovative progress from Kazatomprom’s research into the production of rare metals and rare earth metals from uranium solutions.

5.7. HEALTH, SAFETY, ENVIRONMENT AND SOCIAL RESPONSIBILITY

The track consisted of 14 oral and 7 poster presentations (21 total). Contributions included regulation frameworks and risk-based assessments for mining and milling uranium facilities, as well as nuclear research facilities supporting uranium materials industries. Presentations were made on scientific techniques for measuring uranium and radon. Results of radiological assessments of water, air and soil were presented for uranium bearing areas and legacy facilities. Contributions on the Rook I Project were made on regulatory licencing applications and stakeholder engagement. IAEA presentations covered perspectives on safety of uranium production activities and publications with specific applications to uranium mining and milling uranium facilities, including safeguards requirements and occupational radiation protection. The presentations and discussions covered regions in Australia, Bangladesh, Brazil, Cameroon, Canada, China, Ghana, Indonesia, Niger, Thailand and the United States of America.

5.8. URANIUM FROM UNCONVENTIONAL RESOURCES

The track consisted of 4 oral and 7 poster presentations (11 total). Contributions included investigations into the extraction and recovery of uranium, thorium, and various rare earth elements from coal and coal ash, desalinization brine, mineral fertilizers, phosphate ore, phosphoric acid, seawater, and water treatment effluent. Extraction and recovery techniques examined included active carbon methods, acid digestion, deposition onto polyethylene fiber, and other statistical modelling techniques to examine efficiencies. The scales of examination range from mineral deposit field-sites to pilot and processing plant facilities, to laboratory settings. The presentations and discussions cover work carried out in Ecuador, India, Indonesia, Jordan, Saudi Arabia, Tunisia, the United Republic of Tanzania and other regions.

5.9. TAILINGS AND WASTE MANAGEMENT

The track consisted of 7 oral and 2 poster presentations (9 total). Four contributions on the Rook I Project were made on the case for integrated water, waste and tailings management, as well as presentations on cemented uranium paste tailings disposal in a purpose-built underground tailings storage facility. Contributions were also made on selective removal and extraction of elements in tailings, soils and stream sediments as well as engineering considerations for evaporation pond structures for uranium leaching solutions. The presentations and discussions cover regions in Canada, China, Portugal and Malaysia.

5.10. URANIUM NEWCOMERS

The track consisted of 5 oral presentations and 3 posters (8 total) in which experts from Australia, Bangladesh, Ethiopia, Jordan, Nigeria, the Philippines, Türkiye, and the United Republic of Tanzania provided the latest updates of their respective Member States' exploration programmes and efforts to become uranium producing countries, or extend uranium production with new mining projects. In addition to the introduction of uranium mining, the country's intention to introduce nuclear power as a means of clean energy production was also discussed.

6. SUMMARY OF PANEL EVENTS

6.1. TECHNICAL PANEL SESSION

Scientific Secretary: B. Moldovan (IAEA)

Panel Moderator: I. Chatzis (IAEA)

Panellists: D. Bellifemine (Environment Protection Authority, Manager, Mining and Radiation); A. Boytsov (Tenex/ Rosatom, Executive Vice President Exploration); S. Elting (WMC Energy B.V., Chief Commercial Officer); L. Grancea (TradeTech, Director Policy and Strategy); C. Polak (Orano Mining, Senior Advisor, Strategy and Partnership); G. Schneider (Namibian Uranium Institute, Executive Director).

The panel session addressed three key themes: (1) The need for innovation in exploration and mining; (2) Supply and demand strategies; and (3) Social acceptance strategies. Discussions centred around how these themes relate to the front-end of the nuclear fuel cycle so as to ensure a sustainable supply of uranium for nuclear fuel, for both the existing and future fleets of nuclear power reactors.

After opening and welcoming remarks by Mr Moldovan and Ms Chatzis, short 10-minute presentations on the key themes were given by the panellists.

Ms Grancea provided information on the current global nuclear reactor fleet, the future of large, small (modular), and advanced reactors, uranium requirements, the uranium market and geopolitical landscape, risks and opportunities for sustainable uranium mining in the near future, and environmental social governance matters with respect to the uranium industry. Demand for uranium is projected to be high in order to achieve the transition to clean energy, and nuclear will have an important role to play. To realize nuclear power's role, however, governments will need to promote uranium industry best practice standards and incentivise companies to adhere to them.

Mr Suijs addressed the evolution of uranium market from the renaissance (2004–2011) to the depression (2012–2018) to reinvention (2019 onwards) and reviewed the last two decades of uranium prices and key market fluctuations and developments, sustainability in the uranium industry, and the near-term future situation. Growth in the nuclear energy sector will depend upon, and be driven by, new technologies and more efficient recycling approaches.

Mr Bellifemine reviewed nuclear industry safety and sustainability from various perspectives, including regulators, government, stakeholders, investors, and local communities, as well as social licence issues, and linkages among social licence, sustainability and safety. The role of a regulator in enabling linkages among social licence, sustainability, and safety is to build trust, ensure safety outcomes, and promote sustainable approaches.

Ms Schneider spoke to the concerns of local and national stakeholders, summarizing the 2006/2007 uranium rush in Namibia, and the establishment of the Namibian Uranium Association, and its vision and mission. With the formation of the Namibian Uranium Association, the uranium industry assumed responsibility for environmental sustainability and demonstrated a clear commitment to responsible mining and exploration, providing for comprehensive uranium stewardship through corporate commitment to social responsibility. A significant outcome of these efforts was an environmental assessment initiative, conducted by government in cooperation with the uranium industry, which produced a 'Strategic

Environmental Management Plan', that is implemented by government, in cooperation with the industry, and represented by Namibian Uranium Association.

Mr Boytsov gave an overview of the United Nations Development Programme's 'Global Goals for Sustainable Development', key factors for sustainable uranium production, a uranium supply and demand projection to 2040, uranium resources by cost categories and mining methods, and uranium mines by status (operating, planned, potential), costs, and capacities. An important area of technological innovation and expansion will centre around in-situ recovery methods, which will maintain a low cost of uranium recovery in a challenging uranium market environment. Rosatom, Russian state corporation, has a diversified uranium production base, a high potential to increase production in favourable market conditions, and is investigating opportunities for diversification in other regions and in other commodities.

Mr Polak described SABRE (Surface Access Borehole Resource Extraction), a new innovative and scalable mining method that can allow for the exploitation of relatively small high-grade orebodies that are either too small or too deep to be mined economically by open-pit or underground mining methods. It is a surface-based, non-human-entry method that uses a single high-pressure water jet placed at the bottom of a drill hole to excavate a mining cavity. Over the course of a five-year testing program, completed in 2021, SABRE was able to achieve key test programme operating objectives, such as targets for cavity diameter, rates of recovery, and mine production rates, with no safety, environmental, or radiological incidents. Due to its less intrusive nature and potentially smaller surface footprint when compared to conventional mining methods, SABRE has significant environmental benefits. Reduced water usage and power consumption also contribute to potential reductions in greenhouse gas emissions and improved sustainability. Additionally, as a nonentry mining method, it has significant safety and radiological benefits.

After the presentations, Ms Chatzis, panel moderator, directed the **first question** to Ms Schneider, regarding the role of the Namibian Uranium Association, and the advantages and benefits of addressing uranium exploration and mining concerns jointly, rather than on a project-by-project basis.

Ms Schneider made three points: (1) Uranium mining and exploration companies in Namibia operate in a geographically confined area. Their impacts on the environment, as well as their mitigation and best-practices efforts, are therefore cumulative, rather than individual and isolated. For example, efforts to avoid ground water contamination. It is important that all companies abide by the same standards of operation, because if one operator does not, the effort of the other operators is less effective and compromised; (2) A joint approach is important in terms of the public perception of the uranium industry. If one company does not adhere to standards, it reflects badly on the entire industry. The public should see that the uranium mining and exploration companies work together, and are, as a group, committed to the Charter of the Namibian Uranium Association, as well as the Association's code of ethics, and that environmental best practices are applied by all operators, not just by individual operators; (3) Finally, there is also the benefit of learning from one another, whereby the most efficient and effective approaches to dealing with an environmental concern from the group of operators can guide the formulation of best practices and development of standards to which all companies can adhere. This is particularly important for newcomers. It provides them with guidance and support from the start, rather than operating in a vacuum and re-inventing wheels. They have the advantage from the beginning of learning from the previous experiences of other companies operating in the region.

Ms Grancea added that, there is no single 'formula' that fits every uranium mining or exploration project, and that for each community, it is important to understand what the community values, and to take into account their concerns and needs. A company that is able to develop such an understanding is more likely to obtain social acceptance when undertaking outreach and local stakeholder engagement.

Mr Belifemine shared an experience in Australia where the Environmental Protection Authority has collaborated with multiple industry players to jointly develop guidance for the transport of uranium. The collaboration provided synergy for innovative solutions and knowledge sharing. It is understood in Australia that one non-compliant player can compromise the whole social acceptance network.

The **second question** was from the audience, directed to the whole panel, about sustainable mining. Specifically, the need for increasing uranium resources that are amenable to low-cost mining methods, and the potential of innovative and new technologies, such as SABRE or the novel application of in-situ mining techniques to unconformity-type uranium deposits, for achieving this need. What is the game-changing potential of such new innovative technologies, and is there a 'balance' between the development of innovative technologies to lower the current cost for mining uranium, and the impact of such technologies in relation to the future discovery of new resources, as well as the long-term impact on the price of uranium in the future?

Mr Boytsov believes that these considerations should not be cast as a 'balance' to be made, but rather, the development and application of innovative technologies for exploitation for current uranium resources and discovery of new resources should be carried out simultaneously, and should not be contingent upon, or delayed, because of the current uranium market economic environment. With regard to future considerations, it is important to recognize that there is a 10-year (or more) time period between deposit discovery (exploration) and the start of mining, and therefore, to ensure a sustained supply of uranium, industry should not only continue development and application of innovative technologies but should increase their efforts. With respect to current considerations, innovative technologies and methods have the potential to improve the economics of existing operations, as well as transform currently sub-economic projects into economically feasible operations.

Mr Polak commented that a mining company should take a very long-term view. In terms of exploration and mining innovations, they should not be sensitive to, or affected by, uranium price variations if production is to be maintained, particularly when a mining company is engaged in a contract with a utility to for 10- or 20-years, or sometimes until the reactor end-of-life. So, a mining company in such an engagement has to be responsible for 10s of years of uranium production. Price cannot have such an impact that it stops production, so a company has to continuously work on developing innovative solutions that lower exploration and mining costs, taking into account the long-term view.

Ms Grancea added that, in a market economy, there is an expectation that ongoing operations will continue so long as prices are affordable, but that there will also be competition among various ongoing and potential projects. Such competition promotes cost-saving measures and innovative approaches, such as exploring for and discovering new deposits that are less expensive to exploit. Research and development is clearly needed to lower uranium exploration and mining costs and environmental impacts, such as reducing emissions and consuming less water, among other concerns.

Mr Bellifemine offered a regulator's perspective on innovation and the introduction of new techniques. It is important to have a regulatory system that is flexible and can accommodate new approaches, including assessing risks that might be associated with new technologies and techniques. One of the issues facing Australia is the lack of available professionals to provide adequate competencies for such risk assessments, which in turn can result in inefficiencies for processing and issuing of approvals in a timely manner, thus impacting how quickly new innovations can come online.

A **third question** was taken from the audience, but was more of a comment than a question, regarding 'sustainability'. Sustainable development is a complex system that requires careful consideration in the context of long-term perspectives, such as 50-years, 100-years, or even beyond. With the global population continually increasing, the need for sustainability becomes even more critical. As the demand for energy rises in response to population growth, so does the associated aggregate carbon footprint. It is important to recognize that as working and lifestyle opportunities for the populace increase, societal benefits transition from smaller to larger scales, and competing perspectives will emerge that may raise concerns and questions about whether increased development is indeed sustainable. Moreover, the complex relationship between safety, society, and population growth must also be taken into account. But, when looking at the broader picture, these aspects converge, and sustainability is facilitated by achieving clean and green energy, which includes nuclear power and attendant exploration and mining of uranium resources. In terms of uranium, its carbon footprint varies depending on mining costs. Inexpensive uranium mining has a smaller carbon footprint, while increasingly expensive mining processes result in larger carbon footprints. As such, the overarching objective should be to reduce our carbon footprint, as it is through this reduction that true sustainability becomes possible.

Mr Polak followed-up with an observation from the earlier Plenary Session presentation on the 'Red Book' that, there is enough uranium available for the remainder of this century. But, it should not be overlooked that natural uranium mined today is composed of approximately 0.7% ^{235}U, which is a fissile isotope and is used to fabricate nuclear fuel, while approximately 99.3% is ^{238}U, an isotope which is not capable of undergoing a fission reaction (it cannot sustain a nuclear fission chain reaction) and is currently not used as a fuel for traditional thermal reactors. But, ^{238}U could be used in new-technology fast-breeder (fast-neutron) and Generation IV Reactors, meaning that a much larger proportion of the natural uranium mined today could be used for fuelling these new-technology reactors, and therefore our resources could potentially represent a much larger and sustainable supply of uranium.

The **fourth and final question**, also from the audience, was directed to Mr Polak concerning Orano's new SABRE mining technology, and whether or not it is applicable to only a specific type and character of uranium deposit, or can it be used to exploit other deposit types? In addition, there was interest in obtaining more information about drill-hole characteristics, recovery, and whether testing has been carried out, potentially for the purposes of commercializing the SABRE technique. It appears that there may be great potential for exploiting small-size, 'pocket type' ore bodies of various uranium deposit types.

Mr Polak indicated that SABRE was developed primarily to exploit the very high-grade, unconformity-type ore bodies in the Athabasca Basin. The technique currently is very specific to the Athabasca Basin. It is not suitable for ores with grades under 1.0% to 1.5%, nor for very deep ore bodies, but feasibility studies are underway to further examine these limitations. So, from this initial SABRE concept, there may be opportunities to expand this new mining technique. With regard to SABRE drill-hole characteristics, recovery, and testing of the system,

as indicated earlier in Mr Polak's presentation, SABRE is a surface-based, non-human-entry method that uses a single high-pressure water jet placed at the bottom of a drill hole to excavate a mining cavity. An access hole is drilled to an orebody and a high-pressure fluid injection tool is then lowered down the hole on a specialized mining string to disaggregate the ore material and form a subsurface cavity. The ore material is optionally ground to a desired size by a drill bit and is air-lifted as a slurry through production tubing to the surface for further processing. The injection and grinding tools are optimally part of an integrated bottom-hole assembly at the lowermost end of a drill string. The bottom-hole assembly also includes surveying equipment to measure the cavity dimensions at intervals during excavation, thus allowing fluid injection adjustments to achieve a desired cavity geometry and dimension. Adjacent cavities can be excavated as long as the previous one has been backfilled. With respect to testing of the system, in 2021 a five-year field-testing program was completed at the McClean Lake property in Saskatchewan, Canada. Four mining cavities were successfully excavated to produce approximately 1 500 tonnes of high-value ore ranging in grade from 4% to 11% U_3O_8 (3.4% to 9.3% U).

With that, Ms Chatzis closed the panel session and suggested further discussions could be had later during the coffee break.

6.2. WOMEN IN NUCLEAR (WIN) PANEL EVENT: WOMEN IN URANIUM EXPLORATION AND MINING: PAST, CURRENT AND FUTURE PERSPECTIVES

Scientific Secretary: A. Hanly (IAEA)

Panel Moderators: A.Hanly (IAEA). S. Hall (USGS)

Panellists: Aliya Akzholova (Kazatomprom NAC); Carmen Good (IAEA); Christian Polak (ORANO Mining); Kateryna Pollakovska (National Taras Shevchenko University of Kyiv and University of Lorraine); Dwi Rahayu (Nuclear Security and Safeguards Research Group PRTRN); Brian Reilly (Cameco Corporation); and Gabi Schneider (Namibian Uranium Institute).

The panel session 'Women in Uranium Exploration and Mining: Past, Current and Future Perspectives' was held in cooperation with Women in Nuclear (WiN) IAEA Chapter to discuss how to ensure the long-term sustainability of nuclear power with respect to gender quality.

The opening remarks were delivered by Olena Mykolaichuk, IAEA Director of the Division of Nuclear Fuel Cycle and Waste Technology. Presentations were delivered by four leading industry panellists: Gabi Schneider, Executive director, Namibian Uranium Institute; Christian Polak, Senior Advisor, ORANO Mining; Brian Reilly, Senior VP and COO Cameco Corporation; and Aliya Akzholova, Acting COO, Kazatomprom NAC.

This was followed by a question-and-answer session between early to mid-career professionals: Dwi Rahayu, Young Scientist on Nuclear Security and Safeguards Research Group PRTRN; Kateryna Pollakovska, PhD Candidate National Taras Shevchenko University of Kyiv and University of Lorraine and Carmen Good, IAEA LEU Bank Project Officer. The discussion was moderated by Adrienne Hanly from the IAEA, Uranium Production Specialist and WiN IAEA Education and Mentoring Officer, and Susan Hall, Uranium Resources Specialist, USGS.

One of the panellists, Aliya Akzholova, spoke about gender equality in Kazakhstan. She emphasized that gender policy should be promoted at the highest level. For instance, in 2022, the President of the Republic of Kazakhstan proposed to increase the proportion of women in

management bodies of companies with state participants to 30 percent. This was echoed by the President of the WiN IAEA Chapter, Janette Donner, who in her opening remarks highlighted that gender policies require support from upper management.

Dwi Rahayu, a young scientist from Indonesia, shared her personal story about how she became interested in nuclear power generation, recalling how during her childhood she often sat in darkness, and wondered what a feasible solution could be for "keeping the lights on".

Adequate services, expertise, and modern technologies are needed to ensure a sustainable supply of uranium raw materials to fuel both operating and future nuclear power reactors. Effective regulation, sound environmental management, training and education are required to minimize the impact of uranium mining and production, and to contribute to public acceptance of the global nuclear industry in general. Women will increasingly play an important part in reaching these objectives in the industry.

7. CLOSING SESSION

7.1. MINING PRODUCTION IN BRAZIL - SANTA QUITERIA PROJECT

L. C. Rodrigues Machado da Silva
Technical Lead
Indústrias Nucleares do Brasil,
Fortaleza, Brazil

The Santa Quitéria Project (part of the Itataia deposit) is an important resource, accounting for approximately 45% of the presently measured and indicated uranium resources in Brazil. In addition to a total of nearly 80 thousand metric tonnes of U_3O_8, the deposit also contains approximately 111 million tonnes of P_2O_5, and the production of both uranium and phosphate from the ore is planned. This includes an annual production of approximately 1 million tonnes of phosphate fertilizers, 220 000 tonnes of dicalcium phosphate (an animal feed supplement), and 2 300 tonnes of U_3O_8, which will be extracted from phosphoric acid during phosphate fertilizer production. Brazil will use all these products to cover domestic demand, and when successfully implemented, the Santa Quitéria operation will account for nearly 75% of the uranium production in Brazil.

7.2. DELIVERING CLEAN ENERGY FUEL FOR THE FUTURE

L. Moger
Vice President, Permitting & Licensing
NexGen Energy Ltd.,
Vancouver, Canada

The Rook 1 project, an advanced uranium project in the in Athabasca Basin, Canada, is under development by NexGen Energy Ltd. The project includes the Arrow deposit, which is a basement hosted unconformity-type uranium deposit with reserves that would support an 11-year mine life. The deposit will be mined underground, with a surface mill and an underground tailings management facility. The project has advanced from discovery in 2014, to an initial resource assessment in 2016, pre-feasibility studies in 2018, to a feasibility study in 2021, and in 2022, an environmental impact statement was submitted.

The project supports the environment and the community thorough environmental, social and governance commitments. The President and CEO of NexGen Energy Ltd. explained that the company has been setting new standards in environmental and social stewardship, including working closely with the communities, regulators, and stakeholders over many years. There is a strong commitment to local indigenous groups and communities, including investments into several programmes that focus on youth, education, health and wellness, and capacity building.

The Arrow deposit will be mined using bulk mining methods using shaft access and internal ramps with longhole and traverse stoping. The deposit is monometallic in nature with no deleterious metals and so processing is considered low risk and predictable. Tailings will be managed underground through an innovative tailings management facility, which will eliminate issues that come with surface tailings, such as disturbance and reclamation requirements. Furthermore, advanced water recycling will lead to reduced need of freshwater.

7.3. URANIUM ENERGY CORP. IS ENABLING THE GREEN ENERGY TRANSITION

A. Adnani
Chief Executive Officer
Uranium Energy Corp,
Corpus Christi, USA

Uranium Energy Corp. (UEC) is a mining company from the United States of America that is purely focussed on uranium mining and describes itself as the fastest growing uranium mining company in the world. The importance of providing uranium to the markets with sound environmental, social, and governance standards (ESG) is emphasised. UEC reviewed how it is approaching ESG. As a result of geopolitical changes, more uranium production from western countries is expected in the coming years, and UEC foresees contributing to this future uranium supply with the resources under their control. The United States of America Strategic Uranium Reserve Program, to which UEC has contributed uranium, was highlighted this as an example of an emerging trend. In-situ uranium recovery was discussed as a promising method for uranium mining in Wyoming in the United States of America. Lastly, the growing demand for uranium, and the potential growth of the uranium mining industry in the United States of America, was discussed.

7.4. URANIUM INDUSTRY: HISTORY, STATUS, OUTLOOK AND CHALLENGES

A. Boytsov
Senior Advisor
Tenex, Rosatom,
Moscow, Russian Federation

The world’s uranium resources are sufficient to ensure the long-term needs of the nuclear industry. Lower-cost uranium resources are, however, decreasing. It is forecasted that by 2040 approximately 37% of all presently identified lower-cost uranium resources will be depleted. In this context the present era of uranium production can be described as the era of inexpensive in-situ leach mining, led by operations in Kazakhstan, that account for 40% of global uranium production. In the future these resources will be depleted, and more uranium will be provided from mines in Australia, and to a smaller extent South Africa, where uranium is not the only commodity produced, so that production costs are still expected to be relatively low in the near-term future. In parallel with the reduced availability of lower-cost uranium, a continuous growth of uranium reactor requirements is forecasted. It is thus recommended to accelerate the

discovery and development of profitable uranium deposits that can fill potential future uranium supply gaps.

7.5. DENISON MINES: URANIUM DEVELOPMENT AND EXPLORATION

D. Cates
President and Chief Executive Officer
Denison Mines,
Toronto, Canada

The history of the Wheeler River Project, in the Athabasca Basin of Canada, was summarized, and focussed on the discovery and delineation of the Phoenix and Gryphon deposits. The Phoenix deposit was initially assessed for underground mining, but when that was found to be subeconomic, the company investigated 30 mining methods with the objective of improving the economics of the project. In 2018, after a prefeasibility study, the in-situ recovery (ISR) method was ultimately selected. The current plan for the Phoenix deposit is to produce 60 million lbs of U_3O_8 over 10 years, proceeding the conventional underground mining of the Gryphon deposit, for a combined 14 year mine life.

The Phoenix deposit is well known in the industry as it has the potential to be the first deposit in the Athabasca Basin to be mined using ISR. This could set new standards for environmental protection, health and safety, and sustainability of mining in the district. In 2019 and 2020, Denison completed the first-of-its-kind ISR field test in the Athabasca Basin at Phoenix. This was followed in 2021 with a commercial scale test pattern and tracer test with positive results. Further test work at the Phoenix deposit included core leach testing, which indicated uranium recovery of up to 97% over a 377-day period. Metallurgical testing was conducted using a 1000 litre uranium bearing solution to support bench-scale evaluations for plant design, and it was confirmed that the plant was able to produce a saleable yellowcake product. A fully permitted ISR feasibility field test has been designed to validate and inform the feasibility study and commenced in 2022. The leaching and neutralization aspects have been tested with positive results and the field test is near completion. An independent NI-43-101 compliant feasibility study is currently in progress.

In closing, Denison indicated that the company is currently investigating multiple projects in the Athabasca Basin for the potential of uranium mining using the ISR method.

7.6. ORANO'S LONG-TERM STRATEGY TO MEET UTILITIES' SECURITY OF SUPPLY

C. Polak
Senior Adviser
Orano Mining,
Châtillon, France

Orano reported on its long-term strategy to supply uranium to the market. The company emphasized that it sees a growing demand for uranium. Orano is committed to providing uranium to its customers while meeting corporate social responsibility. Orano reported that it is geographically diversified with its current uranium production facilities so that uranium supply can be secured. This strategy is also planned with further uranium mining facilities that Orano is currently developing in Canada, Kazakhstan, Mongolia, Niger and Uzbekistan. The

different projects were briefly introduced, and also new innovative technologies that aim at increasing uranium mining efficiency were discussed.

7.7. CAMECO'S SUSTAINABLE PATH TO ENERGIZING A CLEAN-AIR WORLD

B. Reilly
Senior Vice-President and Chief Operating Officer
Cameco Cooperation
Saskatoon, Canada

Cameco reported on its efforts to provide uranium for a growing number of nuclear power projects around the world. Cameco reports that it sees a growing demand for uranium as well as nuclear fuel cycle services globally. The position of Cameco as a uranium producer, but also fuel cycle service provider in uranium refining, conversion, and fuel fabrication, was discussed. In addition, investments in laser enrichment, as well as the nuclear power sector through a potential acquisition of shares of Westinghouse, was presented. Current uranium production, as well as uranium production capacity of Cameco's plants, was reviewed and market fundamentals with regards to future uranium supply and demand was also discussed. Lastly Cameco highlighted its own position in providing supply for the future uranium market, as well as the company's automation efforts and alignment with environment, social, governance.

7.8. CLOSING REMARKS-CHAIRPERSON OF THE SYMPOSIUM

Verbatim as delivered.

S. Hall
Uranium Resource Specialist
United States Geological Survey
Denver, USA

Good morning - wow what a week! Thank you, speakers, and attendees, for your participation in the technical oral and poster sessions and panel discussions. Presentations included advancements in understandings of world uranium provinces and the application of new exploration techniques; new and innovative ideas about waste management, advancements in health, safety, and environmental aspects of mining and better understandings of social responsibilities of uranium extraction; the co-production of other metals that accompany uranium that improve the economics of mining operations; improvements to traditional mining techniques including bio-leaching, and more efficient resins and polymers used in extraction; and advanced data analysis and machine learning as applied to exploration and production that give us a peek into the future. Uranium resource experts presented information on the development of nuclear programs worldwide and analysis of supply and demand providing us with a more holistic understanding of the adequacy of uranium supply.

Why are these topics important? In short, all provide deeper understandings of the sustainable production of uranium.

Perhaps I can provide a cautionary tale from my home country from which uranium has been produced for over 80 years to illustrate the importance of your work. In many regions in the United States, production is challenged by an environment of distrust arising from the poor environmental track record of historic uranium mining. In those communities most negatively impacted by ongoing contamination related to legacy mining, trust is low. Often these regions are those in which the identification of additional unmined resources, based on geologic

favourability, is most certain. It is difficult to reengage members of these communities into the risk-based decision-making process of environmental remediation or of mine permitting because they are no longer willing to absorb risk.

The Colorado Plateau, a region I have been studying, provides an example of a uranium province thus impacted. The Navajo Nation is a sovereign region populated by native American Indians within the states of Utah, New Mexico, and Arizona that covers a large portion of the most prospective uranium region on the Plateau. Here, uranium was mined from the 1940's through the 1980's using techniques and worker protections that are not compatible with modern sustainable mining. Since 2007 the US and Navajo Nation Environmental Protection Agencies and partners have been working to identify the location and extent of mining impacts, to determine the most significant human health risks, to secure funding and begin to mitigate these risks and remediate contamination providing safe drinking water and habitable land and structures to the people of the Nation. This work is scientifically and technically challenging, expensive, and there is no clear end to the ongoing work. Because of this environmental legacy, the Navajo Nation has implemented a ban on future uranium mining that was then adopted by other sovereign Indian Nations. These bans have effectively restricted mining what are estimated to be millions of tonnes of in situ uranium resources. Work that is in progress understanding and mitigating past environmental damage is a step towards re-establishing trust, however it looks doubtful that trust will be rebuilt sufficiently to reopen these lands to future mining.

The information presented at URAM this week illustrates how applying the best minds to help develop sustainable and environmentally sensitive mining methods can provide solutions. We recognize the importance of engaging local communities as we seek consent to mine, to protect worker safety, and to consider multiple uses of land when we contemplate mining. This is how we move forward in assuring that uranium production in support of nuclear power continues. You are part of that solution as your work this week has demonstrated. And what amazing work that is!

The future of uranium production is brighter because of you. Thank you for all you have done, and I look forward to following your accomplishments in the future. Safe journeys to all of you until we meet again.

7.9. IAEA'S CLOSING REMARKS

As prepared for delivery.

M. Chudakov
Deputy Director General
International Atomic Energy Agency
Vienna, Austria

I would like to thank you for taking part in the URAM-2023 International Symposium on Uranium Raw Material for the Nuclear Fuel Cycle. This year's Symposium has had a strong focus on innovation for sustaining future uranium resources and production—a vital task for the future of nuclear energy.

As you know, this Symposium takes place every four years and this year's edition follows four previous URAM events. This week's Symposium, organized in cooperation with the World

Nuclear Association, was originally scheduled to take place last year in Vienna. But it had to be postponed due to the global pandemic.

As I hold the honor and privilege to be the final speaker of the Symposium, I would like to provide you with some final statistics that I think are worth mentioning.

Indeed, we have had an outstanding level of participation for a hybrid event, totaling around 258 participants and 121 observers, drawn from 63 countries and 3 international organizations[1]. About 157 attended the Symposium in-person.

This week there was a strong confirmation of a forecasted increase in demand of uranium for use as nuclear fuel and this was reflected in the number of scientific contributions in preparation for this event. This includes 134 technical papers from 39 countries, more than 60% of which were presented orally and the rest as posters. In addition, 10 keynote speeches on policy and global supply and demand were delivered at the opening plenary session. Six thought-provoking presentations were delivered at the technical panel which focused on the sustainability of supply of nuclear fuel. This morning, in the closing plenary session, we heard talks from 7 industry leaders and their strong contributions to ensuring a sustainable supply of uranium. We are excited to note that we received 24 contributions to the Young Generation Essay Contest. Four winning Young Generation event presentations were delivered at the opening plenary session on Monday, while the winners were presented with certificates by Director General Grossi.

In that same session, we had the opportunity to learn about policies which recognize nuclear as a low carbon energy source and how this could impact strategies for increased nuclear power and ultimately an increase in demand for uranium. We also heard from four experts on the forecasts for supply and demand for uranium over the next several decades. Although suitable resources exist in the ground, there is a requirement for more uranium exploration and new mine development in the near term to meet the global demand.

Regarding security of supply, there is growing interest in the nuclear industry for diversity of supply of uranium. We were excited to hear this week about a number of exploration projects and new developments globally, including recovery of uranium from phosphate ore in Brazil.

We also heard about the potential of commercial application of in-situ recovery in an unconformity uranium deposit as well as the potential for long-term storage of uranium tailings in underground mine workings. If both innovations are realized, this would represent an opportunity to significantly reduce the environmental footprint of uranium mines and further enhance social acceptance of the industry.

Ladies and gentlemen,

This past week has offered us very exciting opportunities to gain a better understanding of the global uranium market and activities to ensure a sustainable supply of nuclear fuel.

We have had the chance to listen to extremely informative presentations and have had numerous in-depth discussions. In particular, the scientific contributions summarized in Ms Hall's

[1] European Commission, World Nuclear Association, Nuclear Energy Institute

concluding report exhibited significant technical expertise and demonstrated the vitality and innovation that characterize this exciting field.

I would like to take this opportunity to express my thanks to all of you, and especially Ms Hall, for her support as Chairperson of the Symposium and her engagement throughout the entire event. Of course, I also want to highlight the enormous effort made by the International Scientific Programme Committee who evaluated about 170 abstracts and then reviewed and finally accepted 134 abstracts. Please allow me to also thank all Chairpersons from our 10 Technical Tracks and panel sessions and our wonderful conference clerks who kept the Symposium running smoothly.

Finally, I would be remiss not to mention the latest edition of our Young Generation event. These future experts have once again sent a very strong message that youth are the future scientists, engineers, regulators and leaders who will ensure uranium continues to be mined and processed safely and efficiently. Thanks to all 24 young professionals who took part in the Essay Challenge—and congratulations to the winners from Cameroon, The Gambia, Indonesia, and Kazakhstan.

This youth event underscored the importance of young people for the future innovative technologies for the recovery and purification of uranium for nuclear fuel. It also highlighted the key role of women, including a vibrant side event hosted by Women in Nuclear. It has reminded us once again why the Agency is providing scholarships for female graduate students in the nuclear field through its Marie Sklodowska Curie Fellowship Programme.

As we get ready to look back on this event, please be reminded that on the URAM-2023 Symposium website, you will be able to find all submitted papers and working material. I expect the final Proceedings of the Symposium will be published later this year.

In conclusion, some final thanks are in order, starting with our scientific secretaries, Mr Brett Moldovan, Ms Adrienne Hanly and Mr Mark Mihalasky, along with their associates Ms Carmen Good, Ms Nancy Herter, Ms Lucia Suarez-Leon, and Ms Sakura Gyay De Goyaz. All of them have worked hard to make this a very successful event.

I wish you all pleasant and safe travels back to your home countries and all the best in your future activities.

I declare the URAM-2023 International Symposium on Uranium Raw Material for the Nuclear Fuel Cycle adjourned.

8. CONTENTS OF THE SUPPLEMENTARY ELECTRONIC FILES

The supplementary electronic files can be found on the publication landing page at www.iaea.org/publications. For ease of reference the content is organized in the following folders.

1. List of participants, Symposium programme;
2. Orals and posters organised by track title;
3. Winning essays from competition for students and early career professionals (as submitted).

ANNEX I. LIST OF ORALS IN THE SUPPLEMENTARY ELECTRONIC FILES

Paper	Presenter	Country	Paper Title
Track name: Nuclear power and energy markets			
14	Luis Eduardo LOPEZ	Argentina	Uranium exploration, resources, demand and supply in Argentina. An update.
76	Alexander Boytsov; Yuri Ulyanin	Russian Federation	Uranium industry: history, status and outlook
166	Gabi Schneider	Namibia	Overview of uranium activities in Namibia and the African region
Track name: Applied geology and geometallurgy of uranium and associated metals			
11	Ziying Li	China	A new exudative metallogeny of the hadatu uranium Deposit in the red mottled sedimentary sandstone system of Erlian Basin, north China
17	Sarala Selambakkannu	Malaysia	Economic assessment on adsorption performance of thorium using amine-based ion imprinted polymer: response surface modelling
29	Michel Cuney	France	The diversity of geochemical types of Erzgebirge granites and their potential for hosting uranium deposits: comparison to the French Variscan district
36	Deepak Kumar Sinha	India	Uranium mineralisation associated with magmatic albitite in Geratiyon ki Dhani, Sikar district, Rajasthan, India
38	Saravanan Baskaran	India	Characteristics of uranium mineralisation hosted in Dhanjori Group in Pathargora area, Singhbhum shear zone, eastern India
Track name: Applied geology and geometallurgy of uranium and associated metals			
41	Mohamed Ghoneim	Egypt	The main geological features of uranium provinces in Egypt with emphasis on the role of Nuclear Materials Authority of Egypt.
49	Qinlong Tong	China	Extraction of mineral information using hyperspectral data and prediction of favorable areas for uranium exploration in the Benbatu rea, Bayingobi Basin, China
61	Mingkuan Qin	China	Geotectonic Characteristics of uranium-producing sedimentary basins and mineralization of sandstone-type uranium deposits in northern China
62	Feng He	China	Study on metallogenic mechanism of sandstone-hosted uranium deposit in the Lower Cretaceous of northwest Ordos Basin, Northwestern China

Paper	Presenter	Country	Paper Title
Track name: Applied geology and geometallurgy of uranium and associated metals			
68	Anderson da Silva	Brazil	Mineralogical and Geochemical footprints of the uranium deposits of the Lagoa Real Uranium Province, São Francisco Craton, Brazil
Track name: Applied geology and geometallurgy of uranium and associated metals			
77	Susan Hall	USA	New insights into the formation of sandstone-hosted uranium of the Colorado Plateau Uranium Province, USA
84	Mohan Babu Verma	India	Uranium Metallogeny in Southern India
87	Xiaodong Liu	China	Indosinian Epoch hydrothermal uranium mineralization in northwest China
113	Patrice Bruneton	France	UDEPO: THE IAEA uranium deposits database – 2023 update
117	Gaétan Milesi	France	Structural and lithological controls on unconformity-related uranium deposits of the Athabasca Basin region (Canada)
119	Patrice Bruneton	France	2023 IAEA geological classification of uranium deposits
145	Vitaliy Pryvalov	Ukraine	The transcrustal shear zone of the Ukrainian shield and its control on the distribution of Ukrainian uranium deposits
151	Andrew Kaczowka	Canada	Geometallurgical and evolutionary ore characterization of the high-grade polymetallic cigar lake uranium deposit
158	Eytan Bos Orent	USA	Characterization of U(-V) deposits in the La Sal District, UT and CO (USA) and their relationship to Paradox Basin fluid flow
Track name: Advances in uranium and thorium exploration			
28	Patrick Ledru	France	Exploration and evaluation techniques for sandstone-type deposits
43	Hugo Polo	Brazil	Continental-scale favorability for uranium deposits in Brazil
49	Qinlong Tong	China	Extraction of mineral information using hyperspectral data and prediction of favorable areas for uranium exploration in the Benbatu area, Bayingobi Basin, China
50	Kateryna Poliakovska	Ukraine	Overview of selected pegmatoid-related complex REE-Th-U mineralized areas within the Canadian and Ukrainian Precambrian shields
51	Christophe Bonnetti	France	Trace element mapping by LA-ICP-MS on uraninite: a new tool to decipher the genesis ofuranium mineral systems

Paper	Presenter	Country	Paper Title
Track name: Advances in uranium and thorium exploration			
73	Hudson Angeyo Kalambuka	Kenya	Deep learning modelling of rare earth as a proxy for uranium prospectivity in carbonatites
75	Alexander Boytsov	Russian Federation	Wings – new sandstone type uranium deposit for ISL mining in Namibia
95	Iago Costa	Brazil	An artificial intelligence approach to detect uranium anomalies in airborne geophysical data
114	Kateryna Poliakovska	Ukraine	UDEPO: Exploring new data functionalities
118	Mehdi Serdoun	France	An efficient workflow for predicting various logging variables using simple Machine-Learning programs
Track name: Advances in uranium and thorium exploration			
129	Thomas Obin	France	Graphitic lithologies and related structures linked to unconformity-related uranium deposits of the Athabasca Basin (Saskatchewan, Canada)
132	Malcolm Aranha	India	Towards a quantitative mineral resource assessment of global uranium resources
133	James Sykes	Canada	Baselode Energy Corp.'s Recent ACKIO uranium discovery as a proof of concept for the Athabasca Basin 2.0 thesis: exploring for overlooked near-surface, high-grade uranium deposits outside of the Basin
137	Hervé Toubon	France	Access new resources through innovation
144	Julien Mercadier	France	Geological Model and exploration concepts of unconformity-related uranium deposits in Canada: the approach of the GeomIn3D program
146	Clinton Keller	Canada	Geophysical advancements for uranium exploration in the Athabasca Basin, Canada
167	Irvine R. Annesley	Canada	Deep-seated, crustal structural controls on monazite mineralization at Alces Lake, SK (Canada): Characteristics, evidence, and exploration implications

Paper	Presenter	Country	Paper Title
Track name: Project management and evaluations of uranium and thorium projects			
41	Mohamed Ghoneim	Egypt	The main geological features of uranium provinces in Egypt with emphasis on the role of nuclear materials authority of Egypt
98	Ian Shafer	USA	United States Department of energy Office of legacy management's uranium leasing program
Track name: Underground and open pit uranium mining and milling			
32	Kacham Anand Rao	India	Studies on development of hybrid leaching scheme for recovery of uranium from a medium-grade brecciated limestone type Indianuranium ore
48	Wenming Dong	China	Optimization and its application of mining production techniques for Husab open-pit uranium mine, Namibia
52	Qubo Wu	China	Seismic prospecting technology for the evaluation of metallogenic environment of sandstone-hosted uranium deposits, northeastern China
53	Pauline Moeyaert	France	Towards a digital twin for uranium liquid-liquid extraction operations for Somaïr plant
89	Mohammad Alnaief	Jordan	Evaluation of two commercial resins for the concentration and purification of uranium solution resulting from the alkaline leaching process of central Jordan Uranium deposits
Track name: Underground and open pit uranium mining and milling			
161	Jeff Adams	Canada	Maximizing uranium production using data analysis and modelling tools
Track name: Uranium production by the in situ leaching (ISL)/ in situ recovery (ISR) process			
69	Frederic Guerin	France	ISR mining: lessons learned from various geological and environmental conditions
104	Zhanxue Sun	China	Uranium in-situ bioleaching in the KJET Deposit, northwest China
107	Zhazira Amankeldina	Kazakhstan	Scientific, technological and innovative progress NAC Kazatomprom JSC in the production of rare metals and rare earth metals from uranium solutions
108	Armanbek Omirgali	Kazakhstan	Associated gold recovery during in-situ leaching of uranium

Paper	Presenter	Country	Paper Title
Track name: Health, safety, environment and social responsibility			
9	Irene Opoku-Ntim	Ghana	Measurement of radium and radon exhalation rates in soil samples from Obuasi Municipality a mining town in Ghana using the sealed can technique
44	Phachirarat Sola	Thailand	Assessment of internal dose, external dose, and hazard index of workers surrounding the waste and monazite material storage facility of Thailand institute of Nuclear Technology (TINT).
46	H. Burçin Okyar	International Atomic Energy Agency	IAEA tools for occupational radiation protection in the uranium mining and processing industry (Safety Report, training package and data exchange platform)
59	Guofeng Zheng	China	Research on soil remediation of decommissioned uranium mining and milling sites in China
71	Johanna Blake	USA	Approaches to geochemical fingerprinting of uranium in water and solids
83	Hassane Garba Barke	Niger	Update of uranium production activities in Niger
85	C.J.Guembou Shouop	Cameroon	Radon/thoron in water, air, and soil assessment in the uranium bearing area of Poli, Cameroon
91	Jim Hondros	Australia	An all-hazards approach in uranium mining and processing
100	Nizar Perwira	Indonesia	Safety analysis assessment for severe accident in nuclear fuel cycle facilities
131	Farah Deeba	Bangladesh	Radon and Natural Radioactivity at the coastal environment of Bangladesh: Implication for assessing radiation hazard and the possible uranium mineralization
155	Adam Engdahl	Canada	Rook I Project - Engagement as a Core Value
156	Jon Henderson	Canada	NexGen Energy – Advancing the Rook I Project through the licensing application process for a new uranium mine and mill
162	Daniel Bellifemine	Australia	Implementing a risk based framework and developing an effective regulatory approach
163	Hector Hugo Silver Merado	Brazil	Unusual event classification for a mining and milling uranium facility – preliminary results
164	Sebastien Richet	International Atomic Energy Agency	Evaluation of Member States additional protocol declarations regarding uranium mining

Paper	Presenter	Country	Paper Title
Track name: Uranium from unconventional resources			
39	John Manrique	Ecuador	Content distribution of uranium and rare earth elements + yttrium in the Puyango deposit, Ecuador
93	Dennis A. Mwalongo	United Republic of Tanzania	Unconventional uranium resources in phosphate rocks and mineral fertilizers in east Africa: plant food for thought
109	Wengang Huang	China	A modelling methodology for the evaluation of exploiting uranium-bearing coal deposits using fluidization synergetic mining technology
116	Sihana Sihana	Indonesia	Study on the potential of uranium recovery from phosphoric acid production in Indonesia
22	Othman Nor Azillah Fatimah	Malaysia	Tailored-design of radiation modified ion imprinted polymer adsorbent for selective removal of uranium and thorium
58	Yuqin Dang	China	Current situation and regulatory suggestions for evaporation pond of in-situ leach mining projects in China
141	Andres Cardenas Nino	Portugal	Sequential extraction of major and trace elements in soil and stream sediments of an old uranium mine (Portugal)
152	Kristie Bonstrom	Canada	Rook I Project - Integrated Waste and Water Management
153	Arthur Lieu	Canada	Rook I Project – Novel source-term derivation for cemented uranium paste tailings disposal in a purpose-built underground tailings storage facility
154	Blake Martel	Canada	Rook I Project - Rook I Project as an ideal technical setting for underground tailings disposal
157	Nico Bezuidenhout	Canada	Rook I Project - The use of Features, Events, and Processes analyses to support the development of a mine waste safety case
Track name: Uranium newcomers			
10	Reuben Soja	Nigeria	Harnessing Uranium Potentials for Peaceful application: Nigeria's Preparedness and the Journey so far
80	Mohammad Al-Shannag	Jordan	Jordan Uranium Project: Toward Commercial Production
124	Mohammad Rajib	Bangladesh	Potential occurrence of U-Th and associated minerals in the geological environment of Bangladesh
136	James Quinn	Australia	Development of the Tiris Uranium Flowsheet
140	Dennis Amos Mwalongo	Tanzania	Practical IAEA assistance for Tanzania in the development of national infrastructure for the uranium production cycle based on the newly developed milestones approach

ANNEX II. LIST OF POSTERS IN THE SUPPLEMENTARY FILES

Paper	Presenter	Country	Paper Title
Track name: Nuclear power and energy markets			
65	Kizito Mubiru	Uganda	Multiobjective budgetary planning of uranium production for the nuclear fuel cycle
147	Cheikh Amadou Bamba Dath	Senegal	Knowledge management in the context of growing interests on uranium resources and the introduction of nuclear power in Africa: the importance of regional and international cooperation
168	Loretta Boahemaa Manu	IAEA	Estimation of nuclear materials in the nuclear fuel cycle
Track name: Applied geology and geometallurgy of uranium and associated metals			
13	Laith Freihat	Jordan	Radioactive Minerals in Jordan
27	Kaixing Wang	China	Geology, geochemistry and origin of volcanic type uranium deposit in East Kunlun Orogen, Western China
79	Mero Yannah	Cameroon	Tectonic evolution as a guide for uranium exploration in Cameroon
81	Sayel Aladaileh	Jordan	The Jordan Uranium Project 2013-Present: A Progress Report
102	Chida Yu	China	Geochronology of the Hongshiquan uranium deposit in the Longshoushan Uranium Metallogenic Belt, Northwestern China
122	Faten Boujelbane	Tunisia	234U/238U activity ratios in Tunisian phosphates
Track name: Advances in uranium and thorium exploration			
40	Devendra Pal Singh Rathore	India	Simple and Reliable Analysis of Uranium in Mineralised Rocks, Ores, Beneficiation Products and Other Diverse Matrices: Application of Differential Technique in Laser /LED Fluorimetry- A Green Methodology
Track name: Project management and evaluations of uranium and thorium projects			
115	Aibope Davletiyarova; Natalya Bokovaya; Indira Nurimanova	Kazakhstan	Kazatomprom's experience in accounting and control of natural uranium

Paper	Presenter	Country	Paper Title
Track name: Underground and open pit uranium mining and milling			
8	Islam Azab	Egypt	Improvement of Uranium Surface Mining Operations in Gabal Gattar, North Eastern Desert, Egypt.
21	Azza Sayerdayer	Egypt	Uranium production challenges- Egyptian experience
138	Youcef Bensedik	France	Development and deployment of a gamma ray connected stick for in situ uranium grade measurement at Somair Mine, Niger
Track name: Health, safety, environment and social responsibility			
4	Ioana-Carmen Popescu	Romania	Research concerning the environmental impact of former uranium mining activities on the protected areas in Arad county, Romania
6	Irene Opoku-Ntim	Ghana	The health effects of radon on the population of the Ga South Municipality of the Greater Accra Region, Ghana
42	Mykhailo Chetverik	Ukraine	Nuclear legacy - consequences of uranium ore mining in Ukraine
67	Faith Rukundo	Uganda	Potential Health Risk Assessment associated with uranium mining in Eastern Uganda
72	Berihun Aregga	Ethiopia	Regulatory Framework and Environmental Monitoring at Uranium Abundant Sites in Ethiopia
86	Cebastien Joel Guembou Shouop	Cameroon	Liquid –gas equilibrium for radon concentration in water assessment: a rapid and simple in-situ procedure using SARAD EQF 3200
92	Nofriady Aziz	Indonesia	Managing radiation exposure in nuclear fuel cycle facilites
103	Birhanu Tolawak	Ethiopia	Uranium and Thorium Activity Concentration and Their Associated Radiological Hazards in Raw Material, Waste and Final Product of the Bombawha Kaolin Factor.
99	Pradika Annas Kuswanto	Indonesia	Managing security and safety risk in nuclear fuel cycle facilites
Track name: Uranium from unconventional resources			
12	Dussadee Rattanaphra	Thailand	Study on the determination of uranium, thorium and rare earth elements in coal and coal ash by acid wet digestion method
20	Nils Haneklaus	IAEA	Potential unconventional uranium recovery from phosphates and desalination brine in the Kingdom of Saudi Arabia
30	Ashwin W. Patwardhan	India	Potential Recovery of Uranium Resources from Phosphate Fertilizers Utilized in India

Paper	Presenter	Country	Paper Title
37	Naima Ahmadi	Tunisia	Review on potential uranium and rare earth elements extraction from Tunisian Sra Ouertane Phosphate Ore
57	Mohamed Taha	Egypt	Uranium Recovery from commercial phosphoric acid using active carbon based waste packaging materials
82	Lassaad Mejri	Tunisia	Uranium potential in Tunisia, challenges and opportunities
Track name: Uranium from unconventional resources			
101	Putra Oktavianto	Indonesia	Uranium potential in Indonesia: for energy independence
Track name: Tailings and waste management			
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