IAEA BULLETIN

INTERNATIONAL ATOMIC ENERGY AGENCY

The flagship publication of the IAEA | June 2018

Read online at www.iaea.org/bulletin

URANIUM

From exploration to remediation

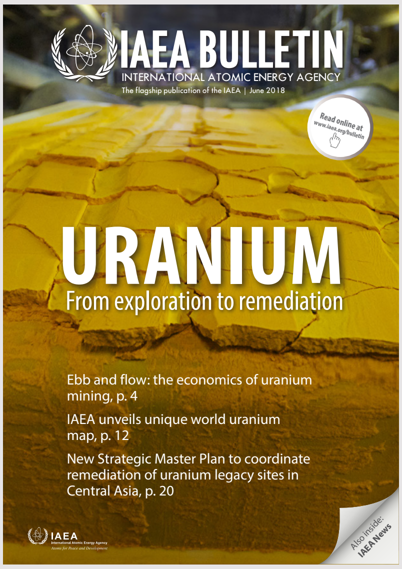
Ebb and flow: the economics of uranium mining, p. 4

IAEA unveils unique world uranium map, p. 12

New Strategic Master Plan to coordinate remediation of uranium legacy sites in Central Asia, p. 20

IAEA
International Atomic Energy Agency
Atoms for Peace and Development

Also inside: **IAEA News**



IAEA BULLETIN
is produced by the
Office of Public Information
and Communication (OPIC)
International Atomic Energy Agency
Vienna International Centre
PO Box 100, 1400 Vienna, Austria
Phone: (43-1) 2600-0
iaeabulletin@iaea.org

Editor: Miklos Gaspar
Managing Editor: Laura Gil
Design & Production: Ritu Kenn

IAEA BULLETIN is available online at
www.iaea.org/bulletin

Cover: Orano

Follow us on

IAEA

The International Atomic Energy Agency's mission is to prevent the spread of nuclear weapons and to help all countries — especially in the developing world — benefit from the peaceful, safe and secure use of nuclear science and technology.

Established as an autonomous organization under the United Nations in 1957, the IAEA is the only organization within the UN system with expertise in nuclear technologies. The IAEA's unique specialist laboratories help transfer knowledge and expertise to IAEA Member States in areas such as human health, food, water, industry and the environment.

The IAEA also serves as the global platform for strengthening nuclear security. The IAEA has established the Nuclear Security Series of international consensus guidance publications on nuclear security. The IAEA's work also focuses on helping to minimize the risk of nuclear and other radioactive material falling into the hands of terrorists and criminals, or of nuclear facilities being subjected to malicious acts.

The IAEA safety standards provide a system of fundamental safety principles and reflect an international consensus on what constitutes a high level of safety for protecting people and the environment from the harmful effects of ionizing radiation. The IAEA safety standards have been developed for all types of nuclear facilities and activities that serve peaceful purposes, as well as for protective actions to reduce existing radiation risks.

The IAEA also verifies through its inspection system that Member States comply with their commitments under the Nuclear Non-Proliferation Treaty and other non-proliferation agreements to use nuclear material and facilities only for peaceful purposes.

The IAEA's work is multi-faceted and engages a wide variety of partners at the national, regional and international levels. IAEA programmes and budgets are set through decisions of its policymaking bodies — the 35-member Board of Governors and the General Conference of all Member States.

The IAEA is headquartered at the Vienna International Centre. Field and liaison offices are located in Geneva, New York, Tokyo and Toronto. The IAEA operates scientific laboratories in Monaco, Seibersdorf and Vienna. In addition, the IAEA supports and provides funding to the Abdus Salam International Centre for Theoretical Physics, in Trieste, Italy.

Ensuring the safe, secure and sustainable supply of uranium

By Yukiya Amano, Director General, IAEA

Uranium is the principal fuel used in nuclear power, a key low-carbon technology for generating electricity. There are presently 451 nuclear power reactors in operation in 30 countries, generating 11% of the world's electricity. Global nuclear power capacity is likely to increase by 2050, according to IAEA projections, although it remains to be seen whether this increase will be modest or substantial.

Estimates suggest that the world will have enough uranium for decades. But it is important that it is mined, produced and managed sustainably to avoid a shortfall. New generations of nuclear power reactors that — depending on the technology used — require less uranium, including small, medium sized or modular reactors, will have a pivotal role to play in the sustainable management of this vital resource.

It is up to each country to decide whether or not to use nuclear power or to mine uranium. The IAEA does not attempt to influence their decision. But if countries opt for nuclear power or decide to explore the possibility of producing uranium, our job is to help them do so safely, securely and sustainably. Nuclear safety and security are also national responsibilities; the IAEA's job is to bring countries together to agree on international standards and learn from each other's experience. Through our advisory services, missions and expert advice, we help national authorities to ensure that uranium, throughout its entire life cycle, is handled safely and securely.

This edition of the *IAEA Bulletin* discusses the status of the industry and its possible future. It outlines the assistance provided by the Agency to countries in uranium mining, milling and mine remediation. It provides an overview of the economics of uranium production (page 4) and includes a case study on the development of a uranium mining project from scratch in Tanzania (page 6). You may also learn how the IAEA's Milestones Approach — a methodology that guides countries and organizations to work in a systematic way towards the introduction of nuclear power — is being applied to the production of uranium (page 10).

You can read about the details of a unique uranium deposit map recently launched by the IAEA (page 12). IAEA safeguards experts explain a less well-known side of their work in nuclear verification: safeguarding uranium mines (page 14). Transport experts from Australia and Malawi highlight the importance of ensuring safety and security in uranium transport (page 18). And we introduce the recently published Strategic Master Plan, which sets the framework for the remediation of former uranium mining sites in Central Asia (page 20). This edition of the *IAEA Bulletin* also features the two-billion-year-old Oklo rock, the world's only known natural nuclear reactor (page 26) and includes an informed overview of the future of uranium (page 24).

The International Symposium on Uranium Raw Material for the Nuclear Fuel Cycle: Exploration, Mining, Production, Supply and Demand, Economics and Environmental Issues brings together experts and interested parties from many fields to discuss the latest research and current issues related to all aspects of the front end of the nuclear fuel cycle.

I hope that this edition of the *IAEA Bulletin* will give you an insight into this less well-known, but fascinating and important area of the Agency's work.

"Through our advisory services, missions and expert advice, we help national authorities to ensure that uranium, throughout its entire life cycle, is handled safely and securely."

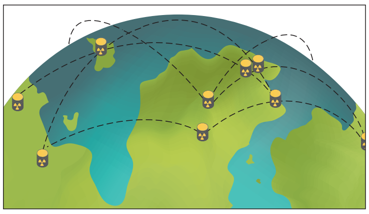
— Yukiya Amano, Director General, IAEA

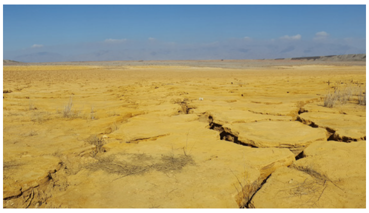
(Photo: C. Brady/IAEA)

(Photo: C. Brady/IAEA)

(Photo Rosatom)

Foreword





World View

IAEA Updates

Ebb and flow: the economics of uranium mining

By Miklos Gaspar and Noah Mayhew

> **"Peaks in the price of uranium are often short-lived, while valleys can last for decades."**
>
> *— Brett Moldovan, uranium production specialist, IAEA*

Mining uranium is just like mining any other base metal, many industry executives say: exploration, licensing, excavation and then shutting down the mine at the end of its useful life. But when you consider radiation protection, long-term management of radioactive waste and the lack of public support surrounding uranium mining in some countries, it is clear that the industry's challenges are more complicated than in the case of other metals. Its economics has been complicated, too, with prices in the last decade or so showing the greatest volatility in history — with a peak of US $300/kilogramme in 2007 and a trough of US $41/kilogramme in 2016 (see chart).

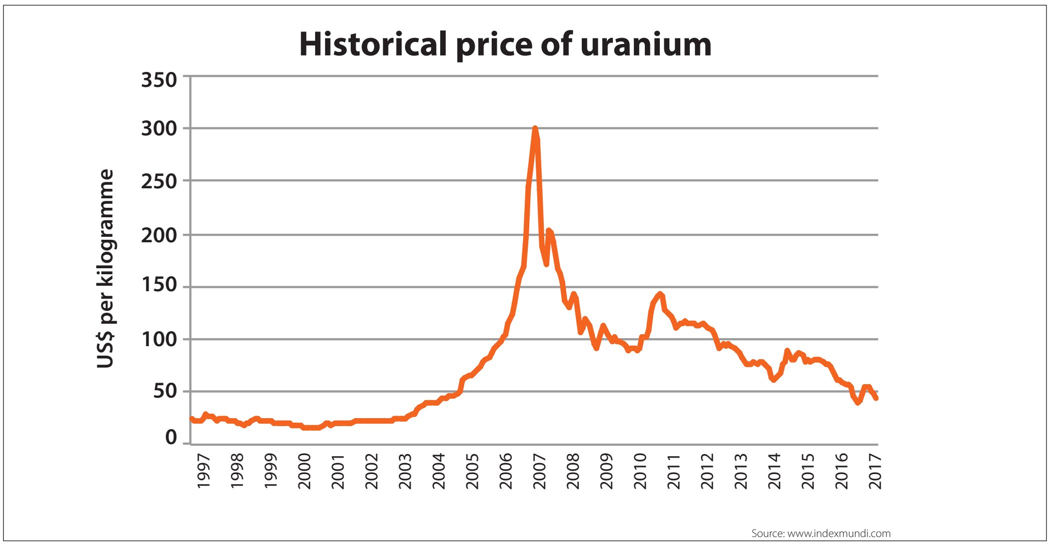
"Over the past few years a surplus of inventory of uranium ore concentrate has developed, leading to lower prices. This is a result of a combination of increased production and reduced demand," said Brett Moldovan, uranium production specialist at the IAEA. "Operating many of the mines under the current price for uranium is a challenge economically."

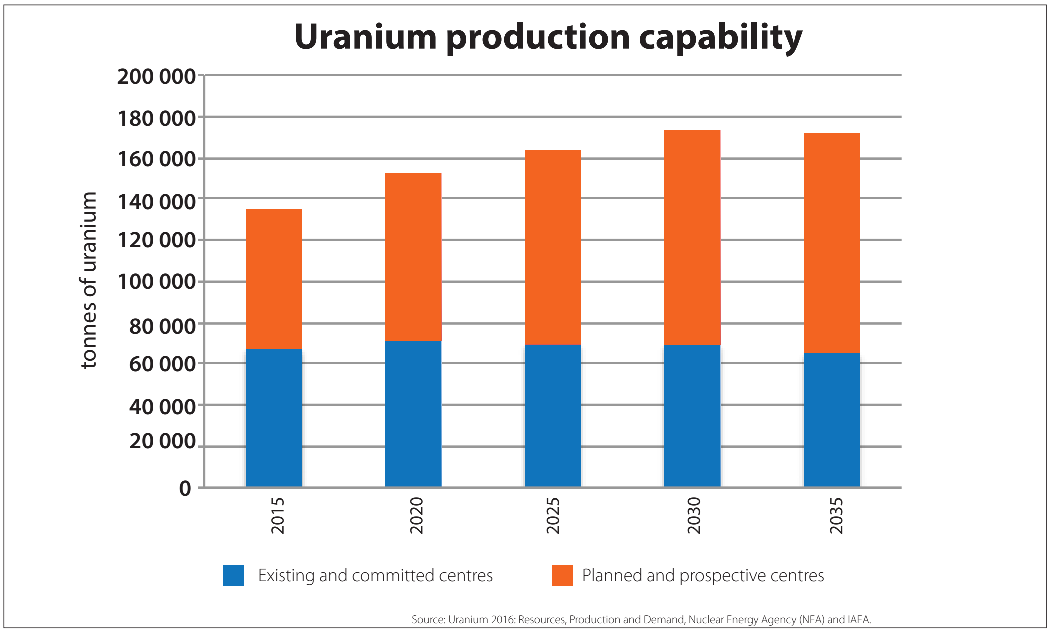
With prices hovering at around US $49/kilogramme today, many of the world's largest uranium mines are in care-and-maintenance mode. "They will be economical to re-start when the uranium spot price is above the cost of production and when price forecasts show that this price will remain stable or increase. The required uranium price for restart is different for each mine as their operating costs vary," Moldovan said. "Peaks in the price of uranium are often short-lived, while valleys can last for decades."

The demand for uranium is mainly determined by nuclear power. There are currently 451 power plants in operation in the world and 59 are under construction, while five were permanently shut down in 2017 and four the year before. The International Energy Agency (IEA) predicts world energy consumption to increase by 18% by 2030 and by 39% by 2050, and the question is what role nuclear power will play in meeting this growing demand.

The IAEA low estimate predicts global energy generated with nuclear power will gradually decline through 2040, to then return to today's levels by 2050. This scenario is specifically designed to create a conservative estimate. The high estimate predicts an increase in nuclear electrical generation capacity from 2016 levels by 42% by 2030 and 123% by 2050. It assumes that current rates of economic growth will continue, along with a growing interest in nuclear power, particularly in East Asia.

Although uranium makes up only 5–10% of the price of electricity generated using nuclear power, it is nonetheless crucial for the long-term sustainability of the industry. According to the latest edition of





Uranium 2016: Resources, Production and Demand — a world reference on uranium jointly prepared by the Nuclear Energy Agency (NEA) and the IAEA — primary global supply is assured until at least 2035 in the low nuclear growth estimate. Known identified resources at the current rate of demand are sufficient for approximately 118 years and even longer if undiscovered resources are included (see chart).

Investing in a uranium mine

Opening a uranium mine requires significant capital investment and is a long process that often involves 10 to 15 years of lag time before the mine begins operation. The cost of the equipment for mining and milling uranium into uranium ore concentrate, which generally takes place on site, is over US $100 million and can even reach into the billions. Thus, private companies and state entities alike must carefully consider long-term economics before opening a mine. Many countries that are new to uranium mining, such as Botswana and Tanzania, have used the IAEA's expertise and assistance to create the necessary infrastructure and the legal, environmental and regulatory framework to open mines. The mines are at an advanced stage of exploration, waiting for a more favourable economic environment.

Most contracts in the uranium business are long term, including price ceilings to protect customers and price floors to protect mines. Although spot prices affect the overall market price, this change happens more slowly. Depending on current market price and the level of a country's nuclear power programme, it can sometimes be more profitable to simply trade uranium than to mine it domestically.

There are countries such as China and India that operate mines mainly to ensure security of domestic supply, with economics being an important but secondary consideration. Most uranium in the world these days is nonetheless mined commercially. Countries like Australia, Kazakhstan and Namibia operate mines for exporting uranium, while others like Canada use the uranium both domestically and for export.

So, what does the crystal ball say? That demand for uranium is forecast to increase in the long run and that prices should increase along with it. But when and by how much is hard to predict, particularly in the light of hesitation by the public in many countries to invest in nuclear power.

"Previous fixes by the industry, through for example strengthening corporate social responsibility or other similar stakeholder engagement efforts, have become less effective given the degree of public scepticism about mineral industries in general," said Hussein Allaboun, Manager of the Jordanian Uranium Mining Company.

Jordan is one of many countries exploring the prospect of uranium production. It has done feasibility studies and constructed a pilot plant to gather the necessary industrial and engineering data. "The project is envisaged as a constituent in a clustered national nuclear energy transformation programme triggered by the country's keen need for a secure source of energy," Allaboun said.

Five years on, Tanzania's progress in uranium exploration

By Aabha Dixit

Environmental sampling at the Mkuju River to measure background radiation conditions before mining begins.

(Photo: Firmi P. Banzi/Tanzania Atomic Energy Commission)

Tanzania is at an advanced stage of uranium exploration and plans to commence mining operations at its first approved mining site as soon as economic conditions become favourable and the price of uranium rises, local experts have said. The IAEA has supported the country in the introduction of its uranium mining programme, including through a 2013 advisory mission to get the project off the ground.

"Five years on, a lot of progress has taken place," said Dennis A. Mwalongo, Head of the Department of Ionizing Radiation at the Tanzania Atomic Energy Commission (TAEC). "The government has worked actively to implement the IAEA Uranium Production Site Appraisal Team (UPSAT) recommendations, which include developing appropriate legal and regulatory measures that comply with international requirements."

> **"Introducing uranium mining requires long-term planning, which includes surveys of the selected exploration sites, soil assessments, building public awareness and capacity building."**
>
> *— Dennis A. Mwalongo, Head, Department of Ionizing Radiation, Tanzania Atomic Energy Commission*

The government has completed the first construction phase of the TAEC laboratory complex, which will provide radioanalytical and calibration services to support regulatory oversight of uranium mining in the country and the wider region, he added.

Introducing uranium mining requires long-term planning, which includes surveys of the selected exploration sites, soil assessments, building public awareness and capacity building, he said. "To achieve this, the IAEA UPSAT mission set the platform by providing a comprehensive assessment on uranium mining possibilities in Tanzania."

The Mkuju River site, the most advanced uranium project in Tanzania, has measured and indicated resources of 36 000 tonnes of uranium and inferred resources of 10 000 tonnes. The site is to be operated by Uranium One, a Russian uranium mining company that plans to produce 1400 tonnes of uranium annually, Mwalongo said. "Uranium mining will contribute to successful and sustainable socioeconomic development for Tanzania. Another important goal is to develop the Dar es Salaam seaport for uranium transport and export."

To meet its growing energy demand, Tanzania is planning to introduce nuclear power on the basis of the 2003 Atomic Energy Act, which authorizes the use of uranium to produce electricity. This law has stringent provisions for the safe use of uranium. The decision makes Tanzania the first country in East and Central Africa ready to introduce nuclear power to generate electricity.

UPSAT mission enhances internal procedures

Key decisions to promote and implement uranium production were based on the IAEA UPSAT mission's recommendations, such as the establishment of regulatory infrastructure, appropriate legislation for safe uranium mining and the harmonization of regulations to protect people and the environment.

In the meantime, the TAEC has developed legislation for exploration, construction, mining and milling, packaging and transport of uranium and the final decommissioning of identified uranium mine sites.

The government has clearly defined specific guidelines on managing radioactive materials and waste and on the protection of workers, the public and the environment, Mwalongo added.

Capacity building, competency-based training, international expertise and specific skill development were provided by the IAEA, the European Commission, the United States Nuclear Regulatory Commission and the Canadian Nuclear Safety Commission.

Getting the public on board

Uranium mining is a diverse and complex activity that requires the involvement of all stakeholders, including the general public.

In support of this, a number of public awareness campaigns and workshops have been conducted by the government to increase awareness of the regulatory requirements of uranium mining. This outreach included central and local government officials, operators, the regulatory authority, non-governmental organizations, students, parliamentarians and civil society. The goal of the regulatory framework is to ensure that the operator manages uranium mining and milling effectively without compromising human health and the environment, Mwalongo said.

First construction phase of the Tanzania Atomic Energy Commission uranium laboratory.

(Photo: D. Mwalongo/Tanzania Atomic Energy Commission)

The uranium laboratory equipment includes a gamma spectrometry system, which will help authorities conduct a proper assessment for uranium found in the country.

(Photo: D. Mwalongo/Tanzania Atomic Energy Commission)

Uranium mining explained

Like other minerals, uranium is typically mined using open-pit technology when the ore is close to the surface and underground mining when it is deeper down. Underground mining requires a high level of ventilation to lower the exposure of workers to radon gas. Radon is produced during the natural decay of uranium.

Globally, the concentration of uranium in the ore can vary from around a few hundred parts per million to up to 20%. From conventional mines, ore is transported to treatment plants or mills where the uranium is purified and concentrated as uranium oxide. As an alternative to open pit and underground mining and when the geology allows, groundwater with added chemicals can be pumped through the uranium deposit to dissolve the uranium in what are called in-situ leaching operations. By injecting alkaline solutions, such as those made with baking soda, or alternatively acidic solutions into the ore through pipes, miners separate uranium from the ore underground and pump the resulting solution back to the surface to recover the uranium.

Close to 60 000 tonnes of uranium are produced annually worldwide. Australia, Canada and Kazakhstan are the top three producers and together account for close to two thirds of world uranium production.

— By Aabha Dixit

Rossing Uranium Mine, Namibia
(Photo: C. Brady/IAEA)

Tried and tested: IAEA Milestones approach now applied to uranium production

By Ayhan Evrensel

The Dolni Rozinka uranium mine in the Czech Republic, one of the about 20 countries producing uranium.
(Photo: D. Calma/IAEA)

You explore uranium, you perform feasibility studies, you develop the project, you mine the uranium, you process and produce it, you transport it, you decommission the project and remediate the site. That's it. Sounds all so simple.

But is it, really?

There may be many influencers that impact this timeline for producing uranium, the element that fuels nuclear power. Of the 170 IAEA Member States, about 20 are currently involved in producing uranium, in varying amounts. About 10 other Member States are undertaking or have completed studies for possible uranium production.

How will a 'newcomer' country or one that wants to come back to uranium production know how to do it right? What steps will they need to take, long before committing themselves to anything, to ensure safe and sustainable production?

Before introducing or reintroducing uranium mining and processing, a wide range of issues needs to be considered. The IAEA has been providing guidance on all these stages through safety standards, publications, meetings, networks and other means. The time has come to consolidate all this guidance.

At the request of several Member States, the IAEA has launched work to apply its Milestones Approach to uranium production.

Eleven years of the IAEA Milestones Approach

In 2007, responding to increasing interest from Member States in adding nuclear power to their energy mix, the IAEA published its *Milestones in the Development of a National Infrastructure for Nuclear Power*. Because the time from the initial consideration of the nuclear power option by a country to the operation of its first nuclear power plant is about 10 to 15 years, the Milestones Approach divided this period into three phases: consider, prepare, construct. In each phase, the country is to handle 19 clearly defined issues, ranging from the legal and regulatory framework to human resource development, from stakeholder involvement to radioactive waste management.

In 2012, this approach was adapted to research reactors, as several Member States that were interested in building them were looking for similar guidance. Again, in three phases — consider, prepare, construct — and highlighting 19 issues, the *Specific Considerations and Milestones for a Research Reactor Project* was aimed at helping national authorities prepare better for safe, secure, sustainable research reactor operations.

Now the work is under way to apply this approach to uranium production. However, getting into uranium mining as a newcomer country is quite different from getting into nuclear power or research reactors.

"Theoretically, you can import any of these reactors and have them constructed or operated anywhere in the world," said Brett Moldovan, uranium production specialist at the IAEA. "But uranium is where you have it, where you find it. We want the newcomers to uranium production to understand that it is a staged process. That you only go forward if you find something promising. If it's suitable and financially viable."

Four stages of uranium production

With those considerations in mind, a meeting in December 2016 kicked off the preparation of a guidance document, which is now close to being finalized.

The guidance is being developed to include four stages where Member States might find themselves, with associated milestones for preparedness:

- those considering exploration or mining of uranium for the first time, or after a hiatus of many years, but without an identified project;
- those seeking to initiate/reinvigorate uranium mining with one or more identified projects;
- established producers of uranium wishing to enhance their existing capacity/capability; and
- historic producers with closed sites/at the stage of closure and rehabilitation/remediation or aftercare.

The document will feature common threads and good practices and is aimed at assisting Member States to identify areas within a stage where they are less prepared and giving advice for a way forward towards a later stage.

"But these are not clear-cut stages," Moldovan said. "A Member State may simultaneously be in more than one of them. And even with excellent work in uranium exploration, with good policies, legislation, regulation and well trained experts, a Member State may remain in the earliest stage, simply because uranium ore may not be there."

The intent of this guidance document is to show the best way for Member States to find, mine and process uranium, and safely clean up the sites at the end of their lifetime, Moldovan added. "Our goal is to help them do it right."

"We want the newcomers to uranium production to understand that it is a staged process. That you only go forward if you find something promising. If it's suitable and financially viable."

— Brett Moldovan, uranium production specialist, IAEA

Tunnel 1200 metres underground in the Dolni Rozinka uranium mine, Czech Republic.

(Photo: D. Calma/IAEA)

IAEA unveils unique world uranium map

By Florencia Caruso

"This latest map is a snapshot of all the current knowledge: a bundle of information, a visual representation of data from various technical documents, all summarized in one place."

— Martin Fairclough, uranium production specialist, IAEA.

The IAEA has launched a comprehensive, online interactive and integrated digital map of the world's uranium distribution and deposits. This second edition of World Distribution of Uranium Deposits was developed with contributions from the Saskatchewan Geological Survey, the Geological Survey of South Australia and the United States Geological Survey.

This edition classifies information by types of deposits and is unique in that it carries a vast amount of new information and knowledge — consolidating data from hundreds of public sources. It is accessible to anyone online and offers advanced interactive tools.

"The aim was to create a complex map that is very simple to use," said Martin Fairclough, a uranium production specialist at the IAEA and one of the map's developers.

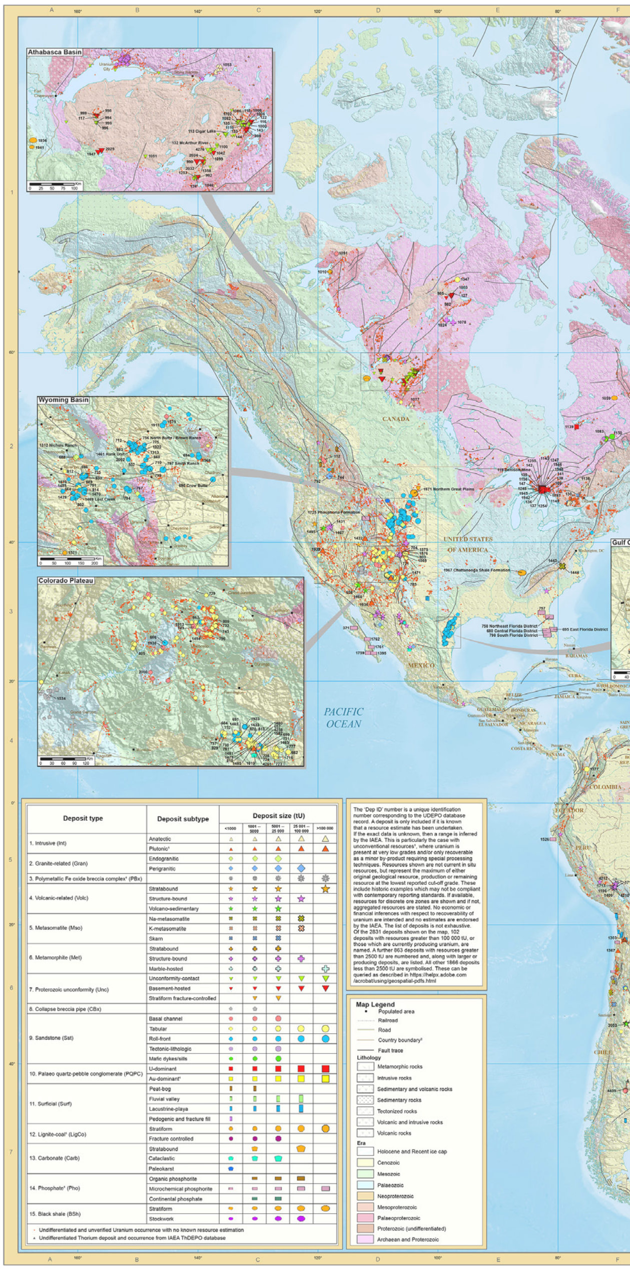
The map has been created for uranium resource and inventory management, geoscience research and the promotion of the discovery and use of uranium. It also provides data relevant to the implementation of nuclear power programmes around the world.

The map is based on data from the *IAEA Uranium Deposits of the World (UDEPO)* database, further outlined in the *Geological Classification of Uranium deposits and Description of Selected Examples* and the *IAEA UDEPO 2016 edition* documents. UDEPO is continuously being updated and includes technical information and detailed geological information on regions, districts and deposits. Both documents, which are complementary to the map, can be downloaded.

Since the publication of the first edition of the map in 1995, the amount of material and the diversity of information available in the world have expanded exponentially, hand in hand with advances in the understanding of uranium deposits. The first edition included 582 worldwide uranium deposits; this latest edition includes 2831.

"This latest map is a snapshot of all the current knowledge: a bundle of information, a visual representation of data from various technical documents, all summarized in one place," Fairclough said.

The map is unique in how it displays this vast amount of information. It classifies uranium deposits into 15 different types, as well as their subtypes. These are represented by different symbols that also



proportionately show the deposits' size. For instance, a star represents all the volcanic-related deposit types, its colours represent its subtypes, and its size represents the deposit's size in tonnes of uranium. A green star, for example, would represent a volcano-sedimentary deposit subtype. And the bigger the green star, the bigger the deposit size.

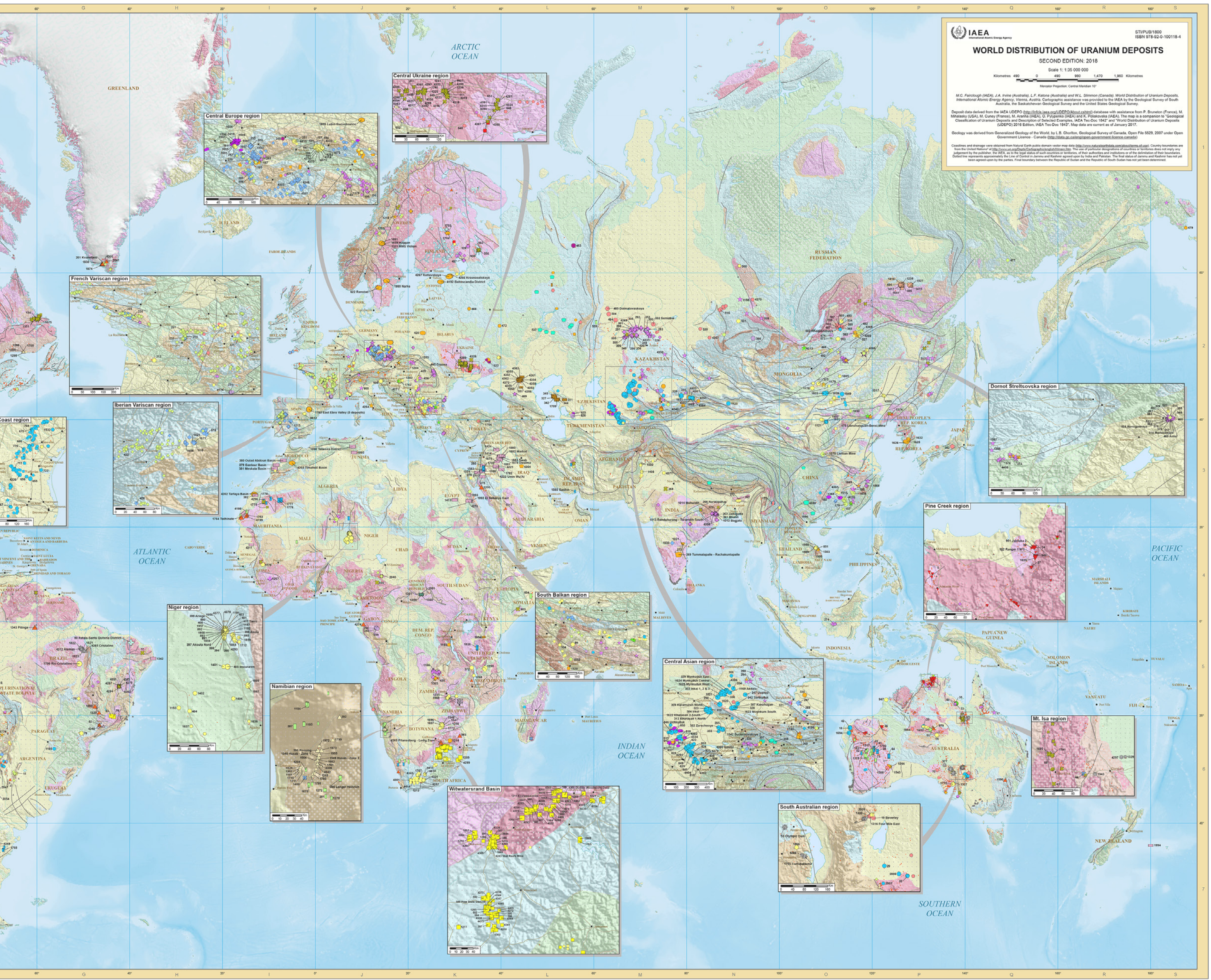
The map's special features allow users to organize and customize all this data. They can turn layers on and off, making them visible or hiding them. For instance, they can choose to display one type of uranium deposit and hide the other 14 types, and then print the version with the exact selected data they are looking for. The benefit of this is that one single product — the map — carries a vast amount of information classified in such a structured way that users can quickly produce a document containing precisely what they are searching for.

Another unique feature is that users can look into individual deposits by clicking on them to see in text format information related to that particular deposit. The map also contains a shaded relief background to simulate topography and enhance the relationships between geology and deposits.

The map can be accessed here: https://www-pub.iaea.org/books/IAEABooks/12314/World-Distribution-of-Uranium-Deposits-Second-Edition

Overview of world distribution of uranium deposits map, Second Edition, 2018.

(Photo: IAEA)



IAEA safeguards at uranium mines provide more complete picture of countries' nuclear activities

By Matt Fisher

IAEA safeguards inspectors visit a uranium mine.
(Photo: D. Calma/IAEA)

IAEA safeguards play a vital role in preventing the spread of nuclear weapons by ensuring that nuclear material remains in peaceful use. Uranium mines and milling facilities handle large amounts of uranium; they are subject to IAEA verification in States with additional protocols to their comprehensive safeguards agreements.

"Verification at uranium mines is performed in the context of consistency analysis," said Russell Leslie, an IAEA safeguards expert. "The information that is obtained during IAEA inspectors' access to uranium mines and mills is checked against State declarations and compared with all of the other safeguards-relevant information available to the IAEA, including inspection activities in the State, to assure that it is meeting its safeguards obligations."

States accept safeguards through the conclusion of safeguards agreements. Safeguards inspectors only conduct verification at uranium mines in countries that have brought into force an additional protocol to their comprehensive safeguards agreement. The additional protocol strengthens the IAEA's verification capability by introducing additional measures — such as increased information about a State's nuclear fuel cycle activities and physical access to relevant locations in the State — to improve the effectiveness and efficiency of safeguards. To date, 132 States have an additional protocol in force — including all countries with operational uranium mines.

These countries are obliged to provide the IAEA with expanded information about their activities related to the nuclear fuel cycle and provide access to relevant locations, including uranium mines and uranium and thorium concentration plants. This enables the IAEA to build increased confidence in the peaceful nature of the country's nuclear programme.

Under the additional protocol, inspectors gather information on the location and operational status of uranium mines and mills and estimate the total annual production capacity of uranium concentration plants. To verify the accuracy of this information, the IAEA may undertake what is known as complementary access to relevant mines and mills to provide further assurance of the absence of undeclared nuclear material and activities.

"Reasonable estimates of the scale of production are the goal of complementary access," Leslie said.

In Australia, one of the world's largest producers of uranium, the IAEA has carried out on average one complementary access to one active uranium mine each year. During a complementary access, national inspectors from the Australian Safeguards and Non-Proliferation Office accompany the IAEA inspectors as they visit the uranium mines and mills. Prior to the inspection, IAEA inspectors are briefed about the mine's status.

During complementary access at uranium mines and mills, the IAEA inspectors may conduct visual observations, collect samples, make non-destructive assay measurements and examine uranium production and shipment records. These activities can be conducted by the IAEA with as little as 24 hours' notice to national authorities.

Visual observation includes an examination of the mine as well as the plant infrastructure. Sample collection involves taking small amounts of both uranium ore and the processed uranium ore concentrate for analysis, as well as taking environmental samples by applying cotton swipes to various surfaces at the mine and sealing them for verification in a laboratory.

"Analysis of the ore concentrate provides more useful information than analysing the unrefined product, the purity of which can vary widely depending on where in the mine it is taken from," Leslie said. The ore concentrate provides crucial data that is important for consistency analysis and for a better overall understanding of a country's nuclear activities, he added.

Non-destructive analysis is a technique used to analyse the radioactive 'signature' of nuclear material, and involves instruments such as gamma detectors. Through this technique, inspectors can confirm on-site the specific nature of nuclear materials at the mine.

The examination of records, conducted together with the mine's staff, includes a review of past mining activity as well as information on current operations. Satellite imagery may also be used in the verification process, Leslie said.

In addition to further confirming the absence of undeclared nuclear material and activities, complementary access to uranium mines is used to confirm the status of mines scheduled for decommissioning or to verify whether a mine is still open and in operation.

Safeguards inspectors visit a uranium storage facility.

(Photo: D. Calma/IAEA)

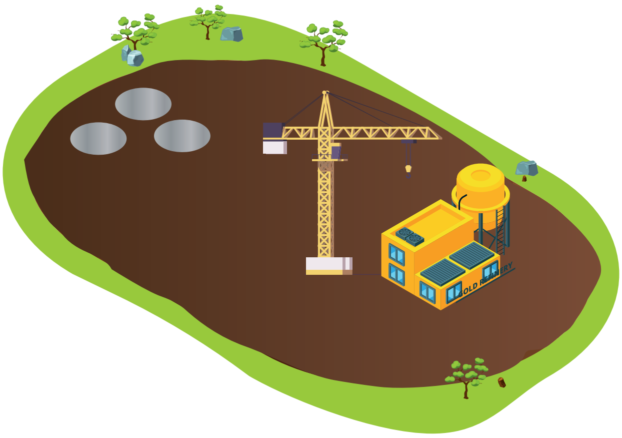
PHASES OF URA

EXPLORATION

10–15 Years

FEASIBILITY

1–3 Years

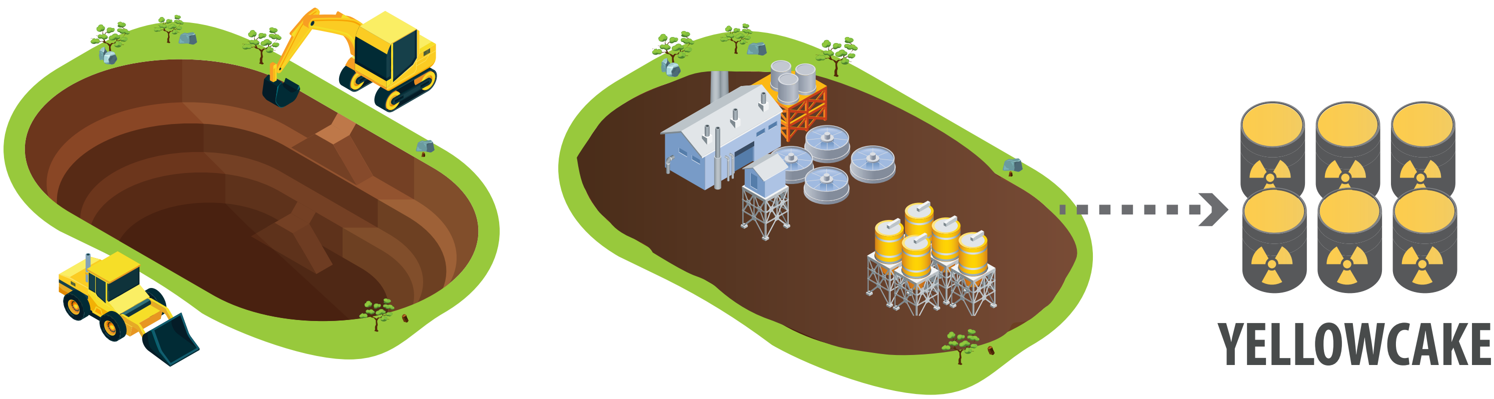


MINE CONSTRUCTION

1–3 Years

ANIUM MINING

(Infographic: R.Kenn/IAEA)

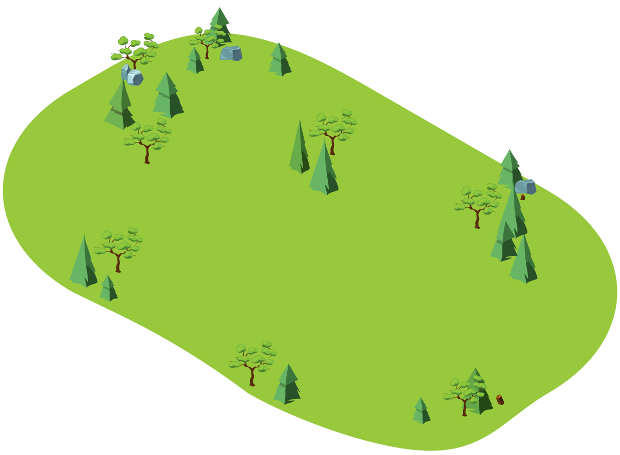


MINING & PROCESSING

5–50 Years

REHABILITATION/REMEDIATION

2–10 years (+aftercare)



Ensuring safe and secure passage for the nuclear industry's vital natural resource

By Nicole Jawerth

> **"Even though the transport of yellowcake is of relatively lower risk than other parts of the nuclear fuel cycle, having high standards of safety and security is vital to building domestic and international confidence in the nuclear industry as a whole."**
>
> *— Robert Floyd, Director General, Australian Safeguards and Non-Proliferation Office (ASNO).*

Uranium shipments are like VIP travellers. They go by land, sea or air and have layovers like any other traveller, but their global influence and appeal to criminals means every detail of their journey is designed to ensure safety and security each step of the way.

"Uranium is only produced by a few countries and is required to produce fuel for most nuclear power plants worldwide, which is why it's a high-value, strategic global commodity," said Robert Floyd, Director General of the Australian Safeguards and Non-Proliferation Office (ASNO). "Given the need to transport uranium globally, it is important that high standards are sustained internationally."

More than 80% of the uranium used worldwide is produced by just five countries. Of the 30 countries that operate 451 nuclear power reactors, few produce their own uranium. This means that more than 50 000 tonnes of uranium ore concentrate are typically shipped each year.

Uranium is a naturally occurring radioactive element. Uranium ore concentrate, or yellowcake, is a concentrated powder form of uranium made by removing impurities from raw uranium ore. (For more information on how yellowcake is made, see page 23.) Most uranium is shipped as yellowcake because it is more cost-effective than transporting unrefined uranium ore.

Although yellowcake poses little radiation hazard, it still requires safe handling. "From a safety perspective, only basic radiation protection measures are necessary," said Eric Reber, a transport safety specialist at the IAEA.

From a security standpoint, explained David Ladsous, an IAEA senior nuclear security officer, "protection measures ensure uranium does not end up in the wrong hands. They are particularly important because uranium has major economic and strategic value that can also motivate theft or sabotage."

The IAEA works with authorities worldwide to train personnel and help develop national safety and security regulations for transporting uranium. National regulations for the safety and security of radioactive material should be designed to meet international standards and be integrated into a global safety and security regime, Reber said. This joint effort covers the whole transport process, from production and packaging to transit routes and delivery. It also addresses potential issues such as piracy.

"Even though the transport of yellowcake is of relatively lower risk than other parts of the nuclear fuel cycle, having high standards of safety and security is vital to building domestic and international confidence in the nuclear industry as a whole," Floyd said.

Building confidence for a stable uranium industry

Confidence is built in part on these national regulations and international standards, because it means all countries in the supply chain are working within the same high standards of safety and security, Ladsous said. This is particularly important for new or small uranium producers and countries such as Malawi that are trying to re-enter the uranium industry.

"Up until recently, one of our biggest challenges was the possibility that our interim competent authority, the Environmental Affairs Department, may not be recognized by other countries as having an acceptable mandate in the transport of radioactive material, including yellowcake, and so some shipments could be occasionally denied," said Burnett Msika, Chief Mining Engineer in the Department of Mines in Malawi's Ministry of Natural Resources, Energy and Mining.

Although, in 2014, Malawi temporarily closed its only mine after five years of operation owing to a crash in uranium prices and high operating costs, the country is actively updating its regulations and training staff with the support of the IAEA to prepare uranium operations to restart.

"That's part of why, through the Environmental Affairs Department, we have made our national atomic energy regulatory authority operational and are building and strengthening human resources and improving collaboration with regulators throughout the transport process," Msika said.

For more experienced exporters like Australia — the third largest producer of uranium and home to the world's largest uranium deposits — the focus is on maintaining confidence as reliable energy exporters.

Australia constantly reviews and updates its regulations and permits and trains staff to ensure its 8000 tonnes of exports each year reach their final destinations, Floyd said. Each Australian state and territory has additional regulations and codes for transport. Together, these set out the requirements for packaging, conveyances, routes and safety and security for transporting yellowcake.

Coordinating this work across state and federal levels is particularly important for such a large country. "Australia is the sixth largest country in the world, so one of the major challenges we have to deal with is covering long distances, often going through vast remote areas. If an incident happens, help can take a long time to arrive. It's important to be prepared and have continuous communication, self-reliance and the right tools," Floyd said.

Australian authorities plan to continue working closely with the IAEA to further strengthen the country's transport regime. Action items for the future include producing a consolidated list of national resources available in the event of an incident, improving training materials and developing a model guide for yellowcake transport plans to enhance understanding of new mining endeavours.

New Strategic Master Plan to coordinate remediation of uranium legacy sites in Central Asia

By Mariam Arghamanyan

"The remediation programme will contribute to long-term socioeconomic development by developing skills and increasing employment."

— Baigabyl Tolongutov, Director, Centre for State Regulation of Environmental Protection and Ecological Safety, Kyrgyzstan

A Strategic Master Plan published in May 2018 is set to help accelerate remediation efforts at former uranium mines in Central Asia. With the necessary funding, the highest-priority sites can be remediated in just a few years.

The new plan, developed under the leadership of the IAEA in cooperation with experts from the region and international organizations, creates a framework for carrying out remediation activities in a timely, coordinated, cost-effective and sustainable manner. Building on European-Union-funded environmental impact assessments and feasibility studies and studies completed by the Russian State energy agency, Rosatom, the plan identifies hotspots and remediation priorities in the region. It also provides risk assessments and cost estimates.

The uranium mining legacy sites are located in the Ferghana Valley area, home to 14 million people and one of the most fertile and densely populated areas of Central Asia. Its Syr Darya River is one of the principal rivers in the region. Among the aims of the projects highlighted in the Strategic Master Plan is the promotion of regional cooperation and a contribution to greater stability and security in the region.

The document identifies seven former uranium production sites in Kyrgyzstan, Tajikistan and Uzbekistan as highest priority for remediation (see map). About €130 million is still needed to finance the remediation, in addition to the €30 million already raised. The European Commission is planning a high-level pledging conference for late 2018 to attract contributions to the Environmental Remediation Account for Central Asia. This account, managed by the European Bank for Reconstruction and Development, will be used to fund remediation activities at the seven sites.

A small number of local and regional remediation efforts have already taken place, but — due to resource limitations — their aim has been to contain rather than clean up contamination. Preliminary remediation activities overseen by Rosatom have commenced in other sites in the region.

"The plan will act as a roadmap to enable the best use of the limited resources available for remediation at national, regional and international levels by aligning these activities with explicitly stated and agreed goals," said Michelle Roberts, a waste safety specialist at the IAEA in charge of the programme.

Uranium mills produce tailings, a sandy byproduct that contains heavy metals and radium. This image shows tailings in Tajikistan's Degmay uranium legacy site.
(Photo: M. Roberts/IAEA)

The plan will be regularly reviewed, re-evaluated and updated to accurately reflect the progress and priorities of the programme, she said.

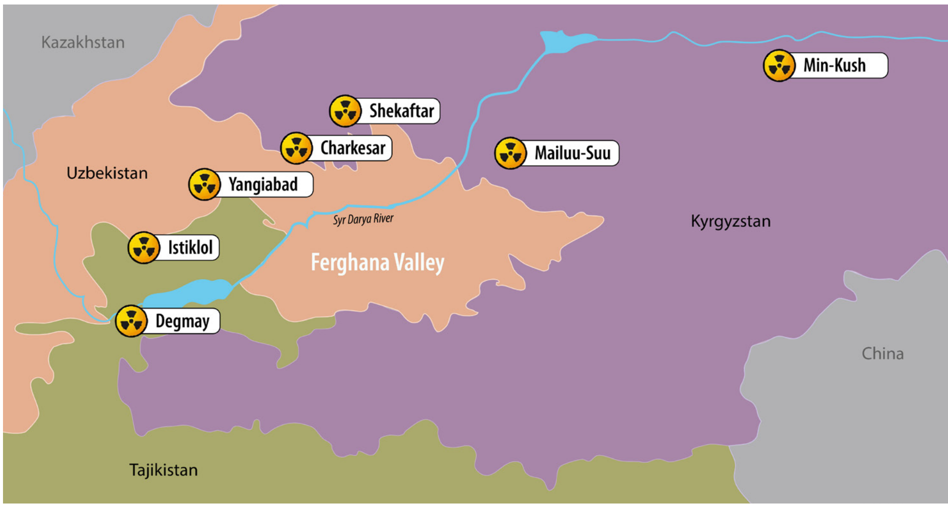
Legacy of mining activities

The uranium mining sites were built in the mid-1940s, at a time when few regulatory provisions were in place for eventual end-of-life management. The sites were used for several decades before being shut down in the 1990s. These mines, and the uranium processing infrastructure on the sites, still contain residues of radioactive and highly toxic chemical contaminants.

Average gamma dose levels at the sites range from 0.30 microsieverts per hour to 4.0 microsieverts per hour, which equals an exposure of between half an hour and four hours of average global natural background radiation. A number of factors, however, could cause the contamination to accumulate or spread.

“Located in a seismically active region prone to earthquakes, landslides and floods, there will remain a risk of the release of contaminated material into the rivers until the sites are remediated,” said Baigabyl Tolongutov, Director of Kyrgyzstan’s Centre for State Regulation of Environmental Protection and Ecological Safety.

A release on this scale could result in long-lasting restrictions on the use of water, leading to a major water shortage with consequences for people’s health and the economy, he said. It may also affect stability and security in the region, particularly if radioactive or toxic materials were to be transported across borders.



Uranium mining legacy sites identified for remediation in the Strategic Master Plan

(Source: Strategic Master Plan)

United Nations resolution

The need for a coordinated approach to remediation was recognized in 2013 by a United Nations General Assembly resolution emphasizing the responsibility of the international community in averting the radiation threat in Central Asia. Addressing the legacy of past uranium mines is also instrumental to the achievement of the United Nations Sustainable Development Goals, Tolongutov emphasized. “The remediation programme will contribute to long-term socioeconomic development by developing skills and increasing employment.”

The plan has been developed by the Secretariat of the IAEA Coordination Group for Uranium Legacy Sites, which is co-funded by the European Union.

Yellowcake coming out of filter press.
(Photo: Orano)

Uranium leaching

How yellowcake is made

When uranium is taken from the earth, the ore or rock typically contains only about 0.1% uranium. Traditionally, to extract it, the ore is first dug from the ground and crushed. The crushed ore is then ground in water to produce a slurry that has the same consistency as beach sand or even talcum powder mixed with water. This slurry is typically mixed with sulphuric acid to dissolve the uranium, leaving the remaining rock particles and most other minerals undissolved; these are called tailings.

Another mining method is called in situ leaching, which involves extracting the uranium directly from the ore without interfering much with the ground. Nearly half the world's production now comes from this type of mining. In situ leaching works by adding acid or alkali plus an oxidizer to groundwater and injecting it into the uranium ore, where it circulates, dissolving the uranium. The solution containing the dissolved uranium is then pumped to the surface for further processing.

Both of these mining methods produce a liquid with uranium dissolved in it. When required, any leftover tailings are filtered out. The uranium is precipitated from the liquid, filtered and dried to produce a uranium oxide concentrate, which is then sealed in drums. This powdery concentrate can be bright yellow (this is why it is known as 'yellowcake') or, if dried at high temperatures, dark green.

Once yellowcake is further processed and, in most cases, enriched, it can be made into nuclear fuel. Yellowcake is produced by all countries in which uranium is mined. It is only mildly radioactive.

— By Laura Gil

The future of uranium as a sustainable source of energy

By Noah Mayhew

Yellowcake is packed in special, tightly sealed steel drums similar in size to oil barrels. Each weighs no more than 350 kilogrammes when full.

(Photo: D. Calma/IAEA)

According to the International Energy Agency, global energy consumption could see an increase of up to 18% by 2030 and 39% by 2050. This will increase the demand for various sources of energy — including nuclear power, and therefore uranium.

"As new power reactors come online and others are retired, proper supply and management of uranium will be a critical factor in energy supply in the coming decades," said Adrienne Hanly, uranium resources specialist at the IAEA. "Uranium-based fuel is expected to remain a basic, reliable source for low-carbon nuclear power. How we utilize this fuel will greatly depend on the development of new technologies and strategies for sustainable resource management."

Even under the IAEA's low case prediction for the future of nuclear power — which would see nuclear energy's share fall from today's 11% of the energy market to just 6% by 2050 — nuclear electrical generating capacity would increase by 24%. Under the high case scenario, nuclear power would see a 2.8-fold increase, and nuclear energy's share of the global energy market would increase to 13.7% by 2050.

As new nuclear power technologies mature, in some cases requiring less uranium or using today's nuclear waste as fuel, increase in nuclear power generation does not necessarily mean a proportional increase in the demand for mined uranium. But that demand is expected to rise nonetheless.

How will the industry meet this growth in demand? While there are enough uranium resources accessible with current mining practices for at least 100 years, research is under way to identify different methods for tapping into the world's uranium resources.

Uranium from the sea

One such method consists of extracting uranium from seawater, which contains more than four billion tonnes of dissolved uranium — far outweighing the volume of reasonably assured supply from mining activities on land. Extraction from the sea also promises to be an environmentally friendly and sustainable way to supplement the global uranium supply.

Extracting usable quantities of uranium from seawater is theoretically simpler than from ore. The uranium found in seawater is created by steady chemical reactions between the

Uranium has to be seen as a low-carbon fuel that can help realize many of the United Nations Sustainable Development Goals and climate commitments.

— Harikrishnan Tulsidas, Economic Affairs Officer, United Nations Economic Commission for Europe

water and rocks that contain uranium. And when uranium is taken from the seawater, the same amount later leaches from the rocks to replace it. Success in this research would mean a virtually unlimited supply.

Methods under development for extracting uranium from seawater involve infusing fibres made of polyethylene, a common plastic, with amidoxime, a substance that attracts uranium dioxide and binds it to the fibre. There are approximately three milligrams of uranium per cubic metre of water, or about the equivalent of a grain of salt per litre. After about a month of soaking them, scientists can remove the fibres and treat them with an acid that collects the uranium and makes the fibres suitable for reuse.

Although this method has been researched for decades, its commercialization has not yet proven to be economical given the low price of uranium and the abundance of supply from conventional mines. Over the past five years, the cost of uranium extraction from the sea dropped by a factor of four to US $440 per kilogramme. But the price needs to fall significantly further for this method to be usable on a commercial scale.

Using uranium more efficiently

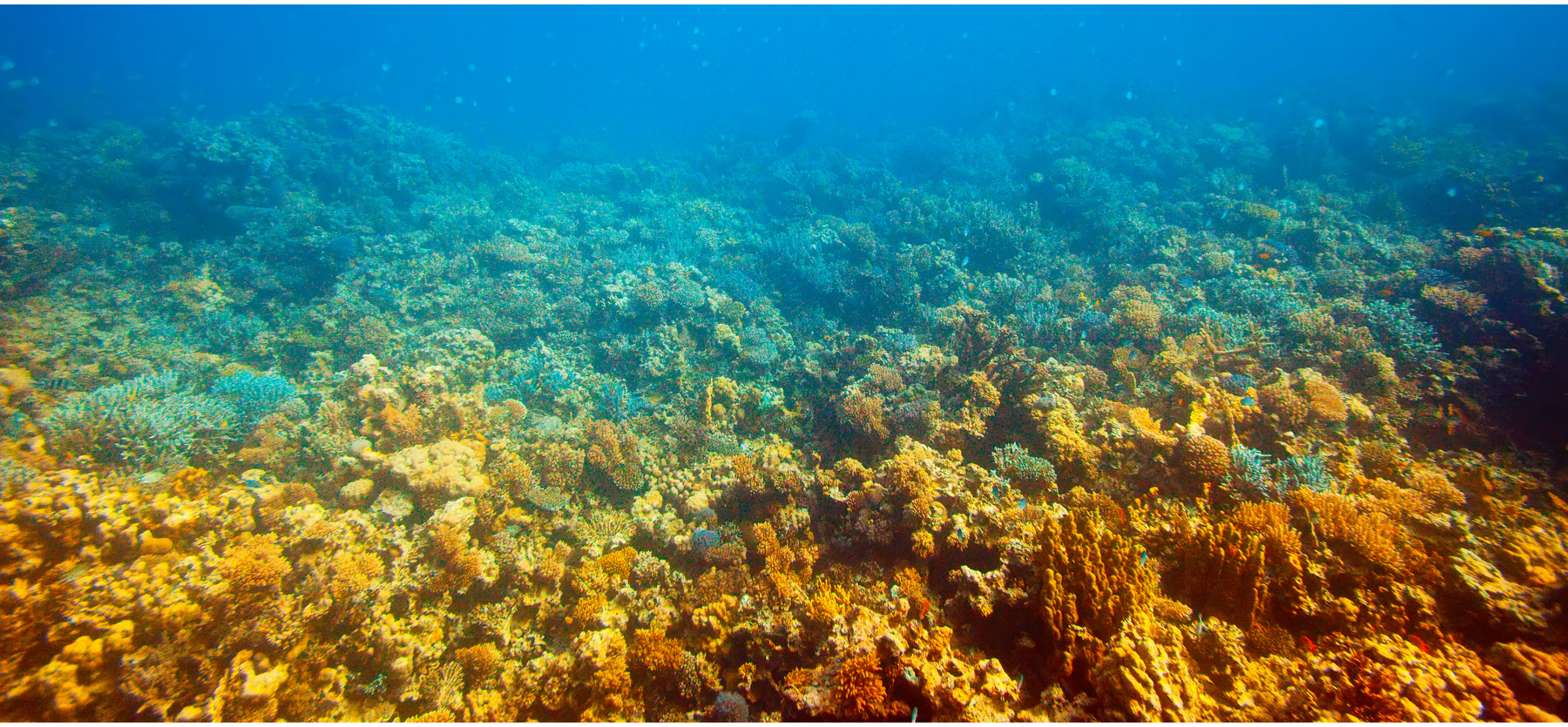
Equally important as sustainable uranium acquisition is the efficient use and management of the uranium. Interest worldwide has increased in the use of small modular reactors (SMRs), thanks to their ability to generate flexible power for a wider range of uses and applications. One advantage of SMRs is that — depending on the technology used — less uranium could be required for the same output.

Large scale SMR deployment could significantly alter demand and the predictability of the market. Today, the industry caters to a constant demand from large reactors, whose supply needs are different from those of small reactors.

In addition to exploring new technologies for obtaining more uranium, the nuclear energy industry will have to examine practices in resource management to ensure sustainability, Hanly said. The IAEA has been working with the United Nations Economic Commission for Europe (UNECE) in recent years to address issues in resource management, including socioeconomic viability, technological feasibility and confidence in estimates.

"Uranium has to be seen as a low-carbon fuel that can help realize many of the United Nations Sustainable Development Goals and climate commitments," said Harikrishnan Tulsidas, Economic Affairs Officer at UNECE. "New technologies will have a critical role to play in making uranium production sustainable."

Seawater contains more uranium than all global deposits on land combined, but its extraction is not currently economical.



Meet Oklo, the Earth's two-billion-year-old only known natural nuclear reactor

By Laura Gil

Samples of Oklo donated to Vienna's Natural History Museum.
(Photo: Ludovic Ferrière/Natural History Museum)

"We want people to learn about natural radioactivity, to make them aware of the fact that radioactivity is all around us, that it's natural, and that at low levels it's not dangerous."

— Ludovic Ferrière, Curator of the Rock Collection, Natural History Museum, Vienna, Austria

Physicist Francis Perrin sat at a nuclear-fuel-processing plant down in the south of France, thinking to himself: "This cannot be possible." It was 1972. On the one hand, there was a dark piece of radioactive natural uranium ore, extracted from a mine in Africa. On the other, accepted scientific data about the constant ratio of radioactive uranium in ore.

Examination of this high-grade ore from a mine in Gabon was found to contain a lower proportion of uranium-235 (U-235) — the fissile sort. Only a tiny bit less, but enough to make the researchers sit back and scratch their heads.

The physicists' first, logical response to such an unusual ratio of U-235 was that this was not natural uranium. All natural uranium today contains 0.720% of U-235. If you were to extract it from the Earth's crust, or from rocks from the moon or in meteorites, that's what you would find. But that bit of rock from Oklo contained only 0.717%.

What did this mean? At first, all the physicists could think of was that the uranium ore had gone through artificial fission, i.e. that some of the U-235 isotopes had been forced to split in a nuclear chain reaction. This could explain why the ratio was lower than normal.

But after complementary analyses, Perrin and his peers confirmed that the uranium ore was completely natural. Even more bedazzling, they discovered a footprint of fission products in the ore. The conclusion: the uranium ore was natural *and* had gone through fission. There was only one possible explanation — the rock was evidence of natural fission that occurred over two billion years ago.

"After more studies, including on-site examinations, they discovered that the uranium ore had gone through fission on its own," said Ludovic Ferrière, curator of the rock collection at Vienna's Natural History Museum, where a part of the curious rock will be presented to the public in 2019. "There was no other explanation."

For such a phenomenon to have happened naturally, these uranium deposits in western Equatorial Africa must have had to contain a critical mass of U-235 to start the reaction. Back in those days, they did.

A second contributing factor was that, for a nuclear chain reaction to happen and be maintained, there needed to be a moderator. In this case: water. Without water to slow the neutrons down, controlled fission would not have been possible. The atoms would simply not have split.

“Like in a man-made light-water nuclear reactor, the fission reactions, without anything to slow down the neutrons, to moderate them, simply stop,” said Peter Woods, team leader in charge of uranium production at the IAEA. “The water acted in Oklo as a moderator, absorbing the neutrons, controlling the chain reaction.”

The specific geological context in what today is Gabon also helped. The chemical concentrations of total uranium (including U-235) were high enough, and the individual deposits thick and large enough. And, lastly, Oklo managed to survive the passing of time. Experts suspect there may have been other such natural reactors in the world, but these must have been destroyed by geological processes, eroded away or subducted — or simply not yet found.

“That’s what makes it so fascinating: that the circumstances of time, geology, water came together for this to happen at all,” Woods said. “And that it was preserved until today. The detective story has been successfully solved.”

A rock sample in the IAEA’s home city

Rock samples from Oklo, some of them recovered during drilling campaigns, are stored in the headquarters of France’s nuclear power and renewable energy company Orano. In early 2018, two half split drill-core samples were donated to Vienna’s Natural History Museum. The donation was made possible by the financial contribution of Orano and France’s Alternative Energies and Atomic Energy Commission (CEA), with the support of the French Permanent Mission to the United Nations and the International Organizations in Vienna. IAEA scientists helped when the sample was delivered to Vienna by monitoring radioactivity levels and facilitating the rock’s safe handling.

The two samples emit a radiation of approximately 40 microsieverts per hour if you stand 5 centimetres away from them, which roughly compares to the amount of cosmic radiation a passenger would receive on an eight-hour flight from Vienna to New York. The museum, which receives 750 000 visitors a year, is used to dealing with radioactive samples since it already displays a number of slightly radioactive rocks and minerals.

“We want people to learn about natural radioactivity, to make them aware of the fact that radioactivity is all around us, that it’s natural and that at low levels it’s not dangerous. Radioactivity is in the floors and walls of our homes, in the food we eat, in the air we breathe, and even in our own body,” Ferrière said. “What better way to explain this than by showing a real sample from Oklo, where nuclear fission occurred naturally billions of years ago?”

The permanent exhibition will show different sources of background radioactivity. Perhaps a world map with the distribution of radioactivity, a radiation detector or Geiger counter or a cloud chamber, will allow visitors to see exposure to natural radiation for themselves.

“Rocks are like books. You can look at the cover and get some basic information, but it’s when you open them that you get the full story,” Ferrière said.

Ludovic Ferrière, curator of the rock collection, holds the Oklo reactor in Vienna’s Natural History Museum. A sample of Oklo will be displayed permanently in the museum as of 2019.

(Photo: L. Gil/IAEA)

An insider's look at uranium production: status, prospects and challenges

By Alexander Boytsov

Alexander Boytsov is advisor to the vice president at Uranium One Group in Moscow. He has 40 years of experience in uranium deposits exploration, resource estimation, mining and processing. Since 1994 he has represented the Russian Federation at the Joint IAEA-Organisation for Economic Co-operation and Development (OECD) Uranium group and served as Co-Chair of the 2011 World Nuclear Association's Nuclear Fuel Market Report.

Boytsov has authored and co-authored over 100 publications in Russia and internationally, including a monography on *Uranium geology, mining and economy* published in 2012.

There will be an oversupply of uranium until at least 2023, according to two recent reports. The Ux Consulting 2018 Uranium Market Outlook and the World Nuclear Association 2017 Nuclear Fuel Report present supply and demand forecasts for the nuclear fuel cycle until 2030 and 2035 respectively.

During both forecast periods, about 10% of global requirements will be provided from secondary sources. These include civilian stockpiles held by utilities and governments, recycled uranium and plutonium or re-enriched depleted uranium. The share of such sources in the overall supply of uranium will gradually decrease over time, however, leaving primary uranium without many alternatives in the long run.

Primary uranium production from existing mines will decrease by 30% by 2035 because of resource depletion and mine closures — and new mines will only compensate for the capacity of the exhausted mines. Both reports show that from 2023 to 2026 uranium demand may exceed supply. To fill the gap and ramp up to the required 30 000 tonnes per year by 2035, new prospective mines should start production in the next ten years. But the problem is that, according to the companies' plans, no development of these future mines has yet been confirmed. In light of this, are global uranium resources and mining capacities sufficient to meet long-term nuclear power plant requirements?

Despite a depressed market, uranium production has continued to grow steadily in the last decade, reaching 62 000 tonnes in 2016, which was a historical maximum for the period since 1983. (Production in 2017 was 59 000 tonnes.) The growth has been mostly due to a surge in production in Kazakhstan, which has increased

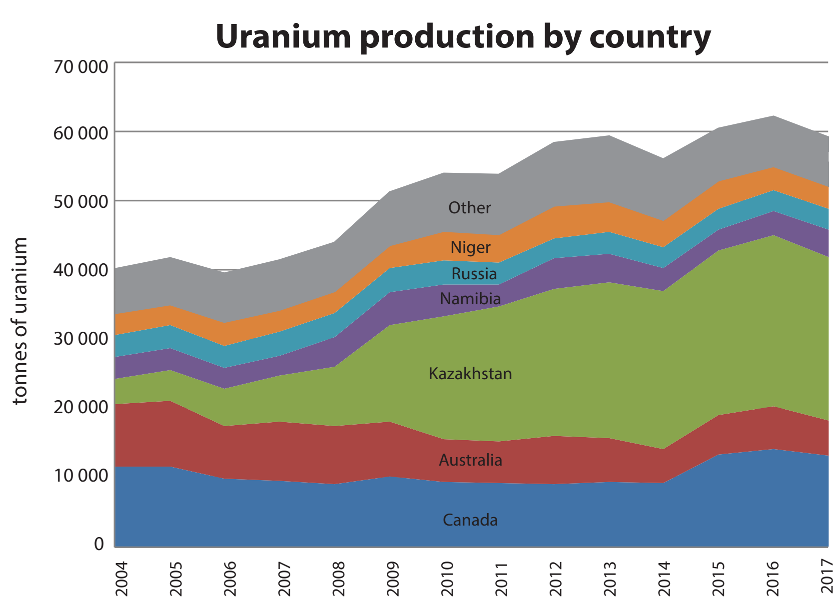


Figure 1. Uranium production by country

Source: compiled by the author, based on uranium-producing companies' public reports.

uranium production six-fold over the past ten years and has been the top producer since 2009 (see Figure 1).

In situ leaching (ISL) is the main uranium mining method in use today. Its share of the world's total production has increased from 20% in 2005 to 50% in 2016 and 2017. However, according to Ux Consulting, ISL mining capacities will start to decline after 2028 because of resource depletion, with production from low-cost ISL mines sharply declining from 2022 onwards. Uranium companies may face economic and technical challenges in developing new ISL mining projects because of higher costs and limited availability of resources.

Only 40% of the 43 currently operating mines produce uranium at a cost below the spot market price, according to Ux Consulting. And only companies with low-cost production or favourable long-term contracts are likely to survive in the current challenging uranium market.

In addition to low uranium prices, companies face constraints related to political, social and environmental factors. These constraints have hampered the development of several uranium projects in Australia, Canada, Kazakhstan, Russia and several countries in Africa. This may result in a drop in uranium production in 2018 by at least 10%.

While Kazakhstan is the world's leading producer today, it may also face all the above-mentioned challenges in the future. It plans to maintain current uranium mining capacities at a level of 25 000 tonnes per year during the next five years, but this may decrease by 40% by 2030 and by 70% by 2035 owing to resource depletion and the closing of old mines.

Enough uranium resources, but at what cost?

For sustainable, long-term production, reliable and low-cost uranium resources are key. Generally speaking, global uranium resources are more than sufficient to ensure the long-term needs of the nuclear industry. However, at the same time, many resources belong in the high-cost categories. After 2020, uranium producers may face a shortage of low-cost resources. During the last decade, total global known uranium resources increased by 21%, but resources in the low-cost category, under US $80 per kilogramme of uranium, decreased by 48% (see Figure 2).

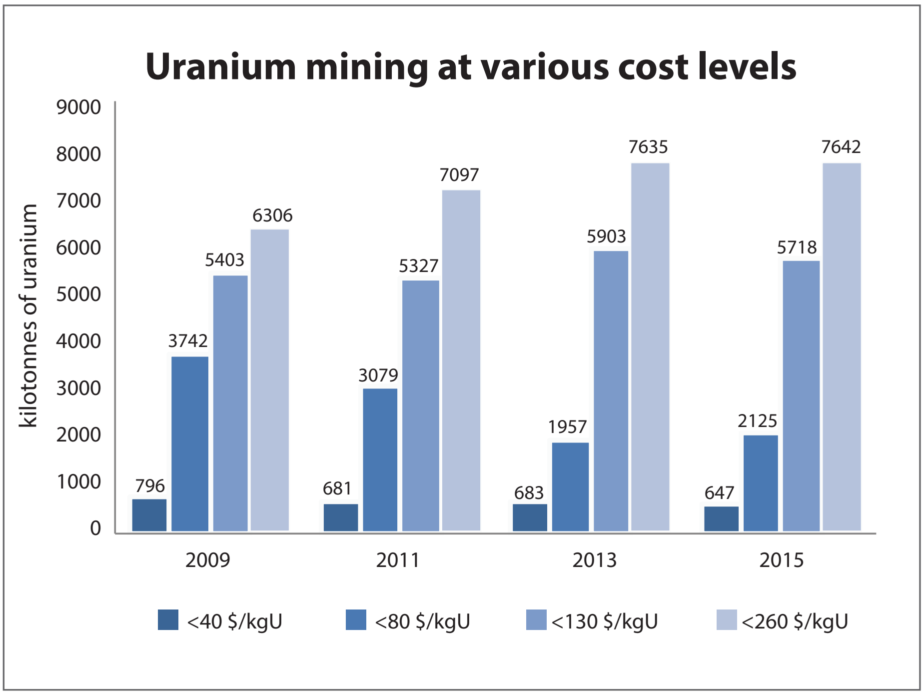


Figure 2. Evolution of uranium resources.

Source: Uranium 2016: Resources, Production and Demand, a Joint Report by the Nuclear Energy Agency and the IAEA.

IAEA expands capacity building to combat childhood cancer

A new partnership will enable the IAEA to better help low and middle-income countries provide increased access to early detection and treatment of paediatric cancer. Under the cooperation agreement with Childhood Cancer International (CCI), signed in early June 2018, CCI and the IAEA will work together to provide specialized training for professionals working in paediatrics, increase awareness and mobilize resources to benefit children with cancer in IAEA Member States.

CCI brings together 188 organizations in 93 countries representing parents and young cancer survivors and works to promote best practices, develop effective, innovative approaches and deliver cost-effective solutions to reduce deaths from childhood cancer. It implements projects in several countries, including Ethiopia, Ghana and Myanmar, to address the healthcare needs of children under treatment, to train fellows in paediatric oncology, to build sustainably run facilities and to establish parent support groups.

Over 300 000 cases of cancer are diagnosed annually in children under the age of 14, and the number of cases is on the rise. A 2015 CONCORD-2 Lancet report estimated that child survival in less developed parts of the world can be as low as 30%, compared with above 80% in high-income countries.

Increasing access to treatment

"This arrangement establishes a collaboration in the fight against paediatric cancer that will increase access to radiotherapy services for children with cancer in developing countries," said Dazhu Yang, IAEA Deputy Director General and Head of the Department of Technical Cooperation. "This partnership will further support our Member States as they respond to the increasing demands for cancer services and specialized skills."

The IAEA has been working closely with Member States to devise and implement programmes which include radiation medicine as part of a multidisciplinary approach to fighting cancer, from prevention and early detection to treatment. In addition to training health professionals, the Agency contributes to quality control measures and to the procurement of equipment for treating paediatric cancers through the transfer of advanced technologies such as proton therapy. It develops guidelines for the safety and protection of patients, including children, who receive radiation.

Thanks to the IAEA's involvement in cancer diagnosis and treatment globally, CCI expects the partnership to bring benefits to young patients and their families worldwide, said Ruth Hoffman, President of CCI. "Our goal is for all children and adolescents with cancer to receive the best possible level of care and have access to diagnostic services," she said. "We can achieve this goal with the help of the IAEA."

— By James Howlett

Online game application wins IAEA student competition

The Malaysian student team presenting their winning entry at the IAEA student competition on innovative approaches to popularizing nuclear science and technology, 31 May 2018, Gyeongju, South Korea.
(Photo: IAEA)

With a computer game application to promote nuclear science, a secondary school team from Malaysia won the international student competition whose winners were announced at the IAEA's Third International Conference on Human Resource Development for Nuclear Power Programmes in Gyeongju, South Korea, in May 2018.

The team from SMK Kuala Besut secondary school named their app "100 Things about Nuclear Science and Life". After launching the educational tool in early 2018, the students found that participating locals and tourists had drastically changed their views about the nuclear industry.

"Before the project, 93% of participants expressed a negative attitude towards nuclear science and technology," said Safyyah bnti Muhammad Nasir, one of the three Malaysian students on the winning team. "But after familiarizing themselves with basic elements of nuclear applications, 96% of respondents had a positive perception of both nuclear energy and science."

The student competition, held in conjunction with the four-day conference, was aimed at fostering interest in nuclear science and technology among secondary school students and was open to participants worldwide. Students aged 14–18 were assigned the task of promoting discussion and awareness of the current and future impact of nuclear science and technology.

Five finalist teams, one each from Hungary, Japan, Malaysia, South Korea and the United States of America, designed and implemented the most innovative projects and won a trip to Gyeongju to present them at the IAEA conference.

Wan Mod Shatar, the teacher overseeing the team at SMK Kuala Besut secondary school, emphasized: "It is important to note that our students are from a fishing village in Malaysia, where knowledge about nuclear science is limited. Through this competition, they not only had to interact with the community, but have also started exploring a new scientific field."

Criteria for initial selection included accuracy, innovativeness, potential impact and gender balance.

"When we first learned about the IAEA International Student Competition, we knew that this was a great opportunity to learn more about the nuclear industry and underline our passion for a world with safe nuclear energy," said Andrew King, Vice-Principal of Alliance Dr. Olga Mohan High School, USA, which sent one of the finalist teams. The students from the high school found that the image of nuclear energy among students was clouded by fear over nuclear weapons and that greater industry outreach was needed to inform students of careers in the nuclear sector.

With the closing of the conference, Yves Bréchet, High Commissioner of the Alternative Energies and Atomic Energy Commission, France, underlined that, from primary school to doctoral programmes, all levels of education are crucial for the future of nuclear energy. In fact, all contemporary issues faced by the nuclear industry have their place in education and training:

- increasing public acceptance of nuclear power requires education of the general public and raises the importance of a scientific education for everybody;
- the need to increase efficiency and safety must mobilize a new generation of engineers more familiar with computer simulation and data analysis; and
- developing innovation will require engineering science, long-term projects and academics from various fields.

The conference attracted over 520 participants and observers from 51 countries and five organizations.

— By Shant Krikorian

IAEA launches Nuclear Energy Capacity Building Hub

The IAEA has launched a new digital platform focusing on workforce planning, leadership, training, stakeholder involvement and human performance to support countries operating nuclear power plants and those considering or developing new nuclear power programmes. The Nuclear Energy Capacity Building Hub allows registered users to join proactive communities of practice for information sharing, capacity building and networking.

Experts can join communities of practice for each topic, provide feedback on IAEA draft publications, explore IAEA e-learning tools, connect to other relevant webpages, browse IAEA publications and access documents from past meetings.

"The Hub offers a unique interactive online space for specialists working in the nuclear field," said Lotta Halt, a training specialist for nuclear power at the IAEA. "It will serve as the IAEA's one-stop-shop for information and discussion on topics related to human resource development and stakeholder involvement for nuclear power programmes."

The Hub was introduced at the Third International Conference on Human Resource Development for Nuclear Power Programmes, which took place in Gyeongju, South Korea, on 28–31 May 2018.

The development of the Hub follows requests from Member States for modernization of the way nuclear professionals communicate. Its goal is to enable faster and more collaborative forums.

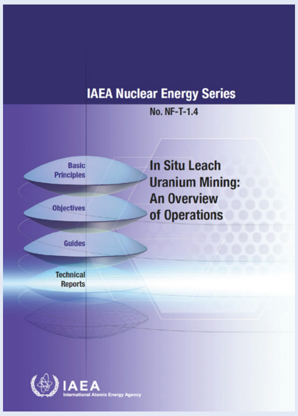
To register and participate, please contact HRD.Contact-Point@iaea.org.

— By Lisa Berthelot

World Distribution of Uranium Deposits. Second Edition

is a comprehensive, online interactive and integrated digital map of the world's uranium distribution and deposits. This second edition was developed with contributions from the Saskatchewan Geological Survey, the Geological Survey of South Australia and the United States Geological Survey. The first 1995 edition included 582 worldwide uranium deposits; this latest edition includes 2831. It offers advanced interactive tools and is also available in print form. (See our article on page 12 for a more detailed overview.)

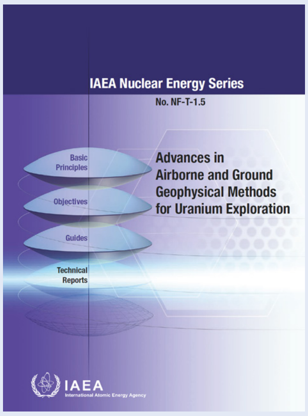
Non-serial Publications; ISBN: 978-92-0-100118-4; English edition; 20.00 euro; 2018
https://www-pub.iaea.org/books/IAEABooks/12314/World-Distribution-of-Uranium-Deposits



In Situ Leach Uranium Mining: An Overview of Operations

provides an historical overview and shows in situ leach or leaching mining experience around the world. This method has become one of the standard uranium production methods. The publication can be used to direct the development of technical activities, taking into account environmental considerations and emphasizing the economics of the process, including responsible mine closure. The publication provides information on how to design, operate and regulate current and future projects safely and efficiently, with a view to maximizing performance and minimizing negative environmental impact.

IAEA Nuclear Energy Series No. NF-T-1.4; ISBN: 978-92-0-102716-0; English edition; 30.00 euro; 2016
https://www-pub.iaea.org/books/iaeabooks/10974/Uranium-Mining



Advances in Airborne and Ground Geophysical Methods for Uranium Exploration

highlights newly designed geophysical instruments and their application in uranium exploration, succinctly describing the modern methods and demonstrating their application with examples.

IAEA Nuclear Energy Series No. NF-T-1.5; ISBN: 978-92-0-129010-6; English edition; 26.00 euro; 2013
https://www-pub.iaea.org/books/IAEABooks/8641/Uranium-Exploration

For additional information, or to order a book, please contact:

Marketing and Sales Unit
International Atomic Energy Agency
Vienna International Centre
PO Box 100, A-1400 Vienna, Austria
Email: sales.publications@iaea.org

ISSN 0020-6067 18-02732

Ministerial Conference

Nuclear Science and Technology: Addressing Current and Emerging Development Challenges

28-30 November 2018
Vienna, Austria

IAEA
International Atomic Energy Agency
Atoms for Peace and Development

#Atoms4Life

CN-262

18-01036

IAEA
International Atomic Energy Agency
Atoms for Peace and Development

https://www.iaea.org/scientific-forum