# Euratom Supply Agency Annual Report 2021

Corrected edition

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Chapter 1
Page 7: Virtual Advisory Committee meeting in October 2021, © ESA

Chapter 2
Page 13: 2021-JHR rack, © CEA
Page 31: Aerial view of enrichment facility Georges Besse II on the Tricastin nuclear site, © Orano-Colin Mathieu
Page 33: Lead Test Assemblies (LTA) manufactured by Westinghouse (Electric Sweden AB) for the Temelín NPP, © CEZ-MF

Chapter 3
Page 36: Equipment in oncology department. Nuclear Medicine, © Alex Tihonov, stock.adobe
Page 38: ITER SNC, © Les Nouveaux Medias – SNC ENGAGE
Page 40: JRC sites in 5 EU Member States, © JRC
Page 47: Uses of medical radioisotopes (Hygieia poster), © NMEu
Page 52: JRC Gelina neutron time-of-flight facility in Belgium, © JRC
Page 54: Four Mile ISL mine Australia, ©Luminita Garcia

Chapter 4
Page 71: Work of trucks and the excavator in an open pit, © evgenii_v – stock.adobe.com

Chapter 5
Page 77: © Zdenek Venclikc – stock.adobe.com

# Foreword

It is my pleasure to introduce the ESA's annual report for 2021.

The annual report is a key contribution to the understanding of the global nuclear fuel market and its evolution and to bring forward ideas to improve the security of supply.

The Euratom Supply Agency has long advocated for the diversification of nuclear material and the related fuel cycle services in the EU. The political and economic events in 2021 and early 2022 seriously impacted the global nuclear market and highlighted the relevance and urgency of ESA recommendations.

As the centre of expertise on nuclear fuel cycle market in Europe, the Agency is presenting in this report a set of recommendations it has developed with a view to addressing the existing and forthcoming vulnerabilities. Let us all make the best of the data and recommendations in this report in order to align and improve our future actions.

Security of supply must be ensured at all front-end stages of the fuel cycle i.e. mining, conversion, enrichment and fabrication. It is of utmost importance that all actors in the single nuclear market adapt to the situation and work on risk preparedness, based on sound risk assessment and including true diversification of supply sources. We are ready to work with our stakeholders, the European industry and utilities, to respond to risks.

The year saw many milestone achievements. The adoption of the new Rules determining how the Agency is to balance demand and supply in the market provides more process-driven transparency and clarity. The renewal of the HEU Exchange MoU was the first deliverables to SAMIRA, and thus of the Beating the Cancer initiative. The issues related to supply of medical radioisotopes now receive more visibility thanks to the new wider format of the European Observatory for the Supply of the Medical Radioisotope.

In fact, we achieved more than seemed possible considering the Agency's scarce resources.

I am grateful, first and foremost, for the incredible dedication, flexibility and hard work of my colleagues. I am proud of the ethical principles that they uphold in everyday work. They were not afraid to embrace innovations and a new working mode. Finally, a sense of humour that allows us to overcome things we have to live (and work) with.

The achievements were also possible thanks to strong cooperation with our stakeholders. We greatly appreciate the continuing engagement of the Advisory Committee and members of its working groups as well as the cooperation with the NMEu and its members. We stand ready to continue working with our partners and fulfilling our mandate in the years to come.

**Agnieszka Ewa Kaźmierczak**
Director-General of the Euratom Supply Agency

# Contents

# Executive summary

The strategic objective of the Euratom Supply Agency (ESA) is the security of supply of nuclear materials and fuel in the EU, for power and non-power uses, by means of the common supply policy. ESA has the exclusive right to conclude contracts for supply of nuclear materials in the EU.

## Key achievements and management in 2021

To ensure continuous supply of nuclear materials and fuel, ESA concluded supply contracts or amendments, and acknowledged notifications of contracts for fuel cycle services or small quantities. ESA adopted and implemented the new Rules determining the manner in which it is to balance demand against supply, which entered into force on 1 July 2021.

Under its monitoring role, ESA collected and analysed market data to identify trends likely to affect the Union's security of supply of nuclear materials and services. The nuclear fuel market observatory issued several market reports and contributed to working groups of the IAEA and the NEA. It also published three EU natural uranium price indices, based on deliveries made to EU utilities.

In its 2020 report, the Agency made several recommendations on security of supply. ESA notes a good response to its earlier recommendations to speed up the arrival of alternative nuclear fuel for the VVER reactors onto the market.

The ESA renewed the 2014 Memorandum of Understanding with the US National Nuclear Security Administration, which facilitates the supply of HEU to European research reactors and medical radioisotope production facilities necessary for the conversion to HALEU.

The European Observatory on the Supply of Medical Radioisotopes revised its mission statement, which provides adequate governance for the challenges ahead. As Observatory's co-chair, ESA liaised and ensured information flows with the appropriate authorities to jointly find solutions to potential shortage scenarios (of Mo-99 and I-131).

An overview of the ESA management, administration, and finances is concluded by the ESA authorising officer's declaration of assurance. The 2022 work programme is annexed.

## Market analysis and recommendations

The report provides an overview of nuclear fuel supply and demand in the EU in 2021, based on information and data coming from the contracts, the annual survey and other sources.

Key enabling factors for the long-term security of supply are diverse sources of supply, lack of excessive dependence on any single non-EU party and viability of EU industry at every stage of the fuel cycle.

Overall, deliveries of natural uranium to EU utilities are well diversified, but several utilities buy their natural uranium from one supplier only. Dependence on a single design of VVER fuel remains a significant vulnerability. Existing contracts for natural uranium, enrichment and conversion services provide good coverage of the EU users' needs until 2030, but this outlook depends on the industry's capacity to deliver on all options included in the contracts.

Russia's invasion of Ukraine has created a new context for the EU's security of supply for nuclear materials. The Agency puts forward a number of recommendations for actions needed to address existing vulnerabilities. It recommends a revision of the risk assessment, including transport and storage aspects, development of the risk preparedness plans, long term diversified contracts and maintaining strategic stocks. It also encourages strategic industrial investment.

## Market and policy developments in the EU and worldwide

The Report presents the overview of Euratom activities. 2021 was an important year for energy policy, which is at the centre of the European Green Deal. Despite the challenges imposed by the pandemic and a major electricity and gas price crisis, several key legislative actions were delivered in support of the Green Deal objectives in the energy sector. The Commission presented an action plan to implement the Strategic Agenda for Medical Ionising Radiation Applications, the follow-up to Europe's Beating Cancer Plan. The Euratom safeguards were able to fulfil all international safeguards obligations entered into under the multilateral agreements concluded. The Commission adopted the Euratom research and training programme work for 2021-2022.

The Euratom perspective is complemented with an overview in EU Member States of the major actions, events, decisions and announcements in the nuclear field.

Finally, the report highlights some worldwide nuclear developments and examines the evolution of the nuclear fuel market.

# Abbreviations

| | |
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| **CIS** | Commonwealth of Independent States |
| **ESA** | Euratom Supply Agency |
| **Euratom** | European Atomic Energy Community |
| **IAEA** | International Atomic Energy Agency |
| **IEA** | International Energy Agency |
| **NEA (OECD)** | Nuclear Energy Agency (Organisation for Economic Co-operation and Development) |
| **(US) DoE** | United States Department of Energy |
| **(US) NRC** | United States Nuclear Regulatory Commission |
| **DU** | depleted uranium |
| **EIA** | environmental impact assessment |
| **ERU** | enriched reprocessed uranium |
| **EUP** | enriched uranium product |
| **HALEU** | high-assay low-enriched uranium |
| **HEU** | high-enriched uranium |
| **lb** | pound |
| **LEU** | low-enriched uranium |
| **LTO** | long-term operation |
| **NatU** | natural uranium |
| **MOX** | mixed oxide [fuel] (uranium mixed with plutonium oxide) |
| **RET** | re-enriched tails |
| **RepU** | reprocessed uranium |
| **SWU** | separative work unit |
| **tHM** | (metric) tonne of heavy metal |
| **tSW** | 1 000 SWU |
| **tU** | (metric) tonne of uranium (1 000 kg) |
| $U_3O_8$ | triuranium octoxide |
| $DUF_6$ | depleted uranium hexafluoride |
| $UF_6$ | uranium hexafluoride |
| **BWR** | boiling water reactor |
| **EPR** | evolutionary/European pressurised water reactor |
| **LWR** | light water reactor |
| **NPP** | nuclear power plant |
| **PWR** | pressurised water reactor |
| **RBMK** | light water graphite-moderated reactor (Russian design) |
| **VVER** | pressurised water reactor (Russian design) |
| **kWh** | kilowatt-hour |
| **MWh** | megawatt-hour (1 000 kWh) |
| **GWh** | gigawatt-hour (1 million kWh) |
| **TWh** | terawatt-hour (1 billion kWh) |
| **MW/GW** | megawatt/gigawatt |
| **MWe/GWe** | megawatt/gigawatt (electrical output) |

# 1. Key achievements

## 1.1. Mission and governance

### Mandate and strategic objectives

The Supply Agency of the European Atomic Energy Community, also known as the Euratom Supply Agency (ESA), was established by Article 52 of the Euratom Treaty [1] ('the Treaty'). It was set up to further the common supply policy for ores, source materials and special fissile materials in the nuclear common market set up by the Treaty. The policy is based on the principle of regular and equal access for all users in the Community to sources of supply.

The prerogatives of ESA stem from the Treaty and secondary legislation. The Agency has the exclusive right to conclude contracts for the supply of nuclear materials, from inside or outside the Community, and has a right of option on nuclear materials coming from inside the Community. It also monitors transactions for services in the nuclear fuel cycle, including by acknowledging the notifications that market players must submit, which give details of their commitments. The Treaty gives ESA legal personality and financial autonomy, enabling it to make independent decisions on matters within its remit.

In the interest of its Treaty missions, the 2008 Statutes [2] entrust the Agency with a market observatory role. This was widened in 2013 to cover aspects of the supply of medical radioisotopes in the EU in the light of Council Conclusions on this issue [3].

The Statutes also determine the Agency's governance. ESA operates under the supervision of the European Commission and is assisted by its Advisory Committee.

> ESA's strategic objective is the security of supply of nuclear materials, particularly nuclear fuel, for power and non-power uses.

### New Rules of the Agency

Following approval by the Commission, the new Rules determining the manner in which ESA is to balance supply and demand entered into force on 1 July 2021. The result of lengthy and concerted efforts by ESA staff, and with the support of both its Advisory Committee and the Commission's Directorate-General for Energy, the new Rules came into effect one year after the Agency's 60th anniversary.

> New Agency Rules, in force since 1 July 2021, determine how ESA performs its tasks.

The Agency's previous Rules were first drafted in 1960. They were partially revised in 1975 to establish a simplified procedure for concluding certain supply contracts. Since then, the nuclear fuel market has changed a lot, mainly due to


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English edition — Legislation — Volume 64, 18 June 2021

Contents

*II Non-legislative acts* — page

DECISIONS

- * **Commission Decision (EU) 2021/986 of 29 April 2021 approving the Decision of the Supply Agency of the European Atomic Energy Community adopting new Agency Rules to determine the manner in which demand is to be balanced against the supply of ores, source materials and special fissile materials** *(notified under document C(2021) 2893)* — 1
- * **Commission Implementing Decision (EU) 2021/987 of 16 June 2021 excluding from European Union financing certain expenditure incurred by the United Kingdom under the European Agricultural Guarantee Fund (EAGF) and under the European Agricultural Fund for Rural Development (EAFRD)** *(notified under document C(2021) 4114)* — 3
- * **Commission Implementing Decision (EU) 2021/988 of 16 June 2021 excluding from European Union financing certain expenditure incurred by the Member States under the European Agricultural Guarantee Fund (EAGF) and under the European Agricultural Fund for Rural Development (EAFRD)** *(notified under document C(2021) 4118)* — 9
- * **Commission Implementing Decision (EU) 2021/989 of 17 June 2021 amending the Annex to Implementing Decision (EU) 2021/641 concerning emergency measures in relation to outbreaks of highly pathogenic avian influenza in certain Member States** *(notified under document C(2021) 4257)* (1) — 41

RULES OF PROCEDURE

- * **Decision of the Supply Agency of the European Atomic Energy Community adopting the Agency Rules determining the manner in which demand is to be balanced against the supply of ores, source materials and special fissile materials, and repealing the Rules of the Supply Agency of the European Atomic Energy Community of 5 May 1960, as amended by the Regulation of 15 July 1975** — 56
- * **Rules of the Supply Agency of the European Atomic Energy Community determining the manner in which demand is to be balanced against the supply of ores, source materials and special fissile materials** — 58

(1) Text with EEA relevance.

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1 http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:12012A/TXT.

2 Council Decision of 12 February 2008 establishing Statutes for the Euratom Supply Agency (O.J. L 41, 15/02/2008).

3 'Towards the secure supply of radioisotopes for medical use in the EU', 3053rd Employment, Social Policy Health and Consumer Affairs Council meeting, 6 December 2010 and 17453/12, ATO 169/ SAN 321, 7 December 2012.

the emergence of many new market players and new trade practices. In addition, ESA's 2008 Statutes strengthened its market monitoring role, making it necessary to change how the Agency collects market data.

The new Rules, adopted by the Agency on 15 January 2021 and approved by the Commission on 29 April 2021, aim to respond to these needs by taking into account new market realities and the Agency's tasks. They also aim to increase legal certainty in the interests of the industry, the Euratom Member States, ESA and the Commission. In particular, they:

- provide new definitions (e.g. 'Community production', 'intermediary', 'user', 'supply contract') to improve clarity;
- formally extend the scope of the simplified procedure (as opposed to the 'centralised procedure' whereby ESA acts as a mandatory intermediary between the parties) so it also covers special fissile materials and applies to them by default, unless the regular supply is endangered;
- require a formal decision to be adopted and published before the centralised procedure can exceptionally apply;
- set conditions for the Agency's potential refusal to conclude a contract;
- specify that any amendment (of whatever kind) to a supply contract must be made by ESA under the procedure used for the original contract;
- streamline procedures for collecting information from users and producers in the interest of clarity and efficiency;
- advise intermediaries on the information they should provide.

The new Rules, together with the Agency's Decision and the Commission Decision, were published in the *Official Journal of the EU* on 18 June 2021 ([4]).

## Advisory Committee

In line with the Statutes, the Advisory Committee ([5]) helps the Agency carry out its tasks by giving opinions and providing analysis and information. The Committee also acts as a link between ESA, producers and users in the nuclear industry, and Member State governments. ESA provides the Committee and its working groups with a secretariat and logistical support.

**Virtual Advisory Committee meeting in October 2021**


*©ESA*

Due to the COVID-19 pandemic and related travel restrictions, the Advisory Committee meetings in 2021 took place online. At its May meeting, the Committee delivered its opinions on ESA's 2020 annual report and on the audited financial and budgetary statements for 2020. The Committee approved the terms of reference for two working groups: on prices and security of supply, and on the European supply of low-enriched uranium (LEU) at 19.75%. The Agency informed the Committee about its 2021 budget and its new Rules.

At its October meeting, the Committee delivered its opinions on ESA's 2022 work programme, the draft budget for 2022 and the budget estimate for 2023. The Agency informed the Committee about the execution of the 2021 budget and progress of the NOEMI (Nuclear Observatory and ESA Management of Information) IT project. The Committee discussed the progress achieved by its two working groups. Following a presentation by ESA, there was an exchange of views on the legal nature of (and the appropriate way to handle) contracts pertaining to the transfer of spent nuclear fuel from a generator to a centralised facility within the Community for its long-term storage and/or disposal. The Committee was informed about the administrative arrangements for implementing the Euratom-UK Nuclear Cooperation Agreement and discussed the agreement's impact on ESA's operations.

4 EUR-Lex - 32021Q0618(01) - EN - EUR-Lex (europa.eu).
5 https://ec.europa.eu/euratom/committee.html.

# 1.2. Principal activities

ESA carries out the following core activities to attain its strategic objective:

- managing contracts for the supply of nuclear materials and/or services in the nuclear fuel cycle, in line with the applicable provisions, for power and non-power uses;
- helping ensure the future supply in the medium and long term by promoting diversification in the nuclear fuel cycle;
- facilitating the continued and equitable supply of medical radioisotopes;
- monitoring and analysing developments in the nuclear fuel market and in relevant R&D fields, publishing its annual report and providing information on the European and global nuclear markets;
- cooperation with stakeholders and partners.

## 1.2.1. Contract management

ESA's activities in this area comprise:

- concluding nuclear materials and fuel supply contracts, pursuant to Article 52 of the Euratom Treaty;
- acknowledging notifications of contracts for small quantities of nuclear materials, pursuant to Article 74 of the Euratom Treaty (6);
- acknowledging notifications of transactions for services in the nuclear fuel cycle, pursuant to Article 75 of the Euratom Treaty.

Nuclear materials that come from inside the Community may be exported only with the Commission's authorisation.

In 2021, under its contract management activities, 248 new references were registered, 40% of which corresponded to new contracts, amendments or supplements to existing supply contracts, pursuant to Article 52. The remaining 60% of references corresponded to notifications of contracts for related services or small quantities.

To make the contract submission and notification process simpler, while ensuring the necessary level of security, ESA supported its stakeholders in the submission and remote completion of contracts and put at their disposal dedicated secure IT tools. In 2021 ESA also began to accept the submission of contracts with an electronic signature that complies with the regulation on identification for electronic transactions in the single market (7).

Following the entry into force of the new Rules, ESA published the forms that must be used to submit supply contracts to be concluded by the Agency (8) and to notify contracts for the provision of services (9). ESA held several meetings with utilities in 2021 to explain the new provisions and provide guidance on how to use the forms.

## 1.2.2. Security and diversification of the nuclear fuel supply chain

In line with its strategic objective and the Commission's policies, the Agency strives to diversify sources of supply in the nuclear fuel cycle for power and non-power uses.

Diversification of supply sources, which also contributes to the viability of the EU's nuclear industry, is a significant way of ensuring secure supplies in the medium and long term. This is explicitly acknowledged by the European energy security strategy (10) and confirmed by the 2021 report on the State of the Energy Union (11).

In its 2020 report, the Supply Agency made several recommendations on contractual terms and procedures. Market players were advised to pursue contractual due diligence to avert supply vulnerabilities, and to ensure a healthy exchange of information as part of an effective security of supply policy. They were advised of the benefits of multiannual contracts with diverse sources of supplies or services. They were also advised to consider special clauses to (i) make it possible to unbundle procurement, (ii) to deal with the licensing and guarantee aspects in case of mixed use of vendor and non-vendor or test fuel, and (iii) to deal with issues pertaining to disclosure of fuel compatibility or testing (proprietary) data.

ESA welcomes the proactive approach taken by market players in 2021, as demonstrated by the numerous meetings with fuel cycle companies and utilities. These contacts gave insights into ongoing negotiations and draft contract terms,

6 Commission Regulation (Euratom) No 66/2006 provides details of how transactions involving small quantities of nuclear materials are handled.
7 Regulation on electronic identification and trust services for electronic transactions in the internal market (EU) No 910/2014.
8 Art. 11 et seq. of the new Rules.
9 Art. 16.
10 COM(2014) 330 final, of 28.5.2014 https://www.eesc.europa.eu/resources/docs/european-energy-security-strategy.pdf.
11 Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2021) 950 final.

and suggest that most market participants heeded ESA's recommendations. Several examples of utilities making best efforts to diversify sources of supply, and to implement the corresponding lead test assembly projects, afforded the opportunity to confirm this assessment with several operators in the EU using VVER fuel.

> Most market participants heeded ESA's recommendations.

ESA also recommended the use of contractual best practices to manage security of supply risks, in particular to ensure that stocks are increased or strategic inventories are set up. As presented in the following chapters, the available data suggests that these recommendations were duly heeded, bearing in mind that whether such inventory levels are sufficient for a particular utility may depend on its profile and risk factors. However, more evidence is needed on whether operators took note of ESA's recommendations to consider carrying out risk exposure assessments and to set up action plans as a result.

There was a good response throughout the year to ESA's earlier recommendations to increase engagement with alternative vendors and cooperation with ESA (and other players) to speed up the arrival of alternative solutions onto the market. ESA continued to monitor and inquire about steps to diversify the supply of fuel for VVER-1000 reactors in Czechia and Bulgaria, as well as the medium- to long-term plans of key EU fuel manufacturers in this respect. However, little progress was made in diversifying the supply of VVER-440 fuel. Licensing by the national nuclear safety regulator is a central element of the introduction of new fuel, to ensure the highest nuclear safety standards.

Through constant contact with several departments in the Commission, including those responsible for competition, trade, the single market and industry, various aspects of the security of supply were addressed in ongoing dossiers, and recommendations were made on the security of supply of nuclear materials and on diversification policies.

## 1.2.3. Market monitoring and analysis

The Supply Agency is responsible for monitoring the market to identify trends likely to affect the EU's security of supply of nuclear materials and services. To that end, ESA:

- monitors developments in the nuclear fuel market and in relevant technological fields;
- publishes a market analysis in its annual report;
- provides information in its publications on the European and global nuclear markets;
- shares information and knowledge with other international market analysis organisations.

### Publications and knowledge sharing

ESA regularly publishes on its website reports and information on price trends ([12]) to create greater transparency in the EU's natural uranium market, reduce uncertainty and help improve security of supply.

In 2021, ESA's nuclear fuel market observatory issued three quarterly uranium market reports ([13]), covering global and specific Euratom developments in the nuclear market. The reports include general data about natural uranium supply contracts concluded by ESA or notified to it, descriptions of activity on the natural uranium market in the EU, and the quarterly spot price index for natural uranium ([14]). The Agency also issues a weekly nuclear news brief for readers in the Commission.

### Annual Report 2020

ESA's annual report remains its principal reporting tool. As in previous years, ESA conducted a survey of EU nuclear power operators. The survey provided a detailed analysis of supply and demand for natural uranium and for conversion and enrichment services in the EU. The Agency published three indices natural uranium prices with calculated weighted averages of the prices paid by EU utilities under multiannual and spot contracts. Its analysis contained forecasts of future demand for uranium and enrichment services and assessed the security of supply of nuclear fuel to utilities in the EU. ESA provided detailed analyses of future contractual coverage for natural uranium and enrichment services and of diversification of supply. It also made an analysis of EU inventories of nuclear material.

12 https://euratom-supply.ec.europa.eu/activities/market-observatory_en.
13 https://euratom-supply.ec.vbgeuropa.eu/publications/esa-quarterly-reports_en.
14 Provided at least three spot contracts have been concluded.

In its 2020 annual report, which had a new graphic design, ESA gave an overview of its own activities and of developments in the nuclear fuel markets and nuclear energy, both in the EU and worldwide. The report set out ESA's findings and recommendations on supply and demand for nuclear fuels ([15]), reflecting the Agency's diversification policy and work on security of supply, and discussed the security of supply of medical radioisotopes. ESA's work programme for 2021 was published together with the report.

The report was published on ESA's website ([16]) on 2 July 2021. Due to the COVID-19 emergency and measures to mitigate its impact, the print version of the 2020 Report was published in October 2021. Special graphics on the cover marked the 60th anniversary of the Agency in June 2020. The report was sent to the European Parliament, the Council of the EU and the Commission, and was presented to the Council Working Party on Atomic Questions.

### Working group on security of supply and prices

ESA worked with the ESA Advisory Committee working group on security of supply and prices, which was given a new mandate in 2021. The working group continued to discuss and offer advice on subjects connected with the operation of the market. The work was pursued in two sub-groups: the first focusing on risks to the long-term security of supply, and the second on fair trade issues and prices.

## 1.2.4. Supply of medical radioisotopes

### SAMIRA

ESA contributes to the implementation of the Strategic Agenda for Medical Ionising Radiation Applications (SAMIRA), which is the energy sector's contribution to Europe's Beating Cancer Plan, and a response to the Council's conclusions on non-power nuclear and radiological technologies and applications.

SAMIRA leads the activities aimed at securing the supply of source materials for radioisotopes production. This means protecting the supply of high-enriched uranium (HEU) until the full radioisotopes are converted into high-assay low-enriched uranium (HALEU), and to explore options for the supply of HALEU in the EU (see below for developments in these areas).

In addition, ESA is tasked with designing and launching a new platform and system for monitoring the supply and long-term forecasts for a broad spectrum of radioisotopes and production methods. ESA has to take into account the further development of the European Radioisotopes Valley Initiative (ERVI), which is crucial for ensuring the endorsement of a wide group of stakeholders and sufficient resources. The Agency closely cooperated in this area with the Commission in 2021. Overall progress in 2021 was slow but uninterrupted.

### European Observatory on the Supply of Medical Radioisotopes

In 2021, ESA continued to lead and coordinate activities to improve the security of supply of widely used medical radioisotopes, focusing on Molybdenum-99/Technetium-99m (Mo-99/Tc-99m). It co-chaired, jointly with the industry association of nuclear medicine (NMEu) ([17]), the European Observatory on the Supply of Medical Radioisotopes ([18]).

Established in 2012, the observatory monitors the EU supply chain of Mo-99/Tc-99m and engages on a variety of topics on the EU supply of widely used medical radioisotopes. The observatory is composed of representatives of the Commission, international organisations and industry.

In March 2021, the observatory's mission statement ([19]) and terms of reference were given a much-needed review. The updated documents, adopted jointly by ESA and NMEu, are meant to provide suitable governance for the observatory's work and the challenges it will tackle. They enlarged the group of participants, offering national governments access to the expertise and information they need to define strategies and policies in this area.

> The European Observatory on the Supply of Medical Radioisotopes now offers national governments access to the expertise and information they need to define strategies and policies in this area.

15 See Section 1.2.2 above
16 https://euratom-supply.ec.europa.eu/publications/esa-annual-reports_en
17 https://nuclearmedicineeurope.eu/.
18 https://euratom-supply.ec.europa.eu/activities/supply-medical-radioisotopes_en.
19 https://euratom-supply.ec.europa.eu/system/files/2021-11/Observatory%20Mission%20Statement%20Final.pdf.

In 2021, the observatory continued its close cooperation with the NMEu's security of supply working group, as well as the transport working group, on the uninterrupted supply of Mo-99/ Tc-99m, particularly as regards transport concerns related to the COVID-19 pandemic ([20]).

Following the unplanned outage of the Australian OPAL research reactor in March-April and the unplanned production stop at the Belgian National Institute for Radioelements Mo-99 production line in December, the Agency ensured a steady flow of information from the NMEu's Emergency Response Team to various stakeholder groups, including the Council Working Party on Atomic Questions ([21]) and the Health Security Committee (HSC) ([22]).

In October, ESA was informed (as a co-chair of the observatory) about a potential shortage of Iodine-131 (I-131) for nuclear medicine therapy in the second half of 2022. The Agency promptly informed the HSC, which is mandated to improve the coordination and sharing of information on national preparedness activities, and the European Medicines Agency (EMA). The EMA subsequently presented the case to the Co-ordination group for Mutual Recognition and Decentralised Procedures – Human (CMDh) ([23]) to raise awareness of the need to change the terms of a marketing authorisation of I-131 from HALEU targets. A work-sharing procedure was agreed to facilitate a coordinated approach and avoid multiple evaluations by individual competent authorities. In parallel, EMA asked the national single point of contact (SPOC) network ([24]) to conduct the criticality assessment at national level to get a detailed view of the impact of the potential shortage.

The observatory met in virtual form in June 2021. The meeting focused on:

- the observatory's new governance framework;
- transport issues related to Brexit and COVID-19 and lessons learned;
- Mo-99 supply monitoring;
- an overview of the future European production chain.

Research reactors and alternative suppliers presented their capacity forecasts. Participants also addressed the possible inclusion of other novel medical radioisotopes, such as Lutetium-177 (Lu-177), within the scope of the observatory. The representatives of the Commission's Directorate-General for Energy (DG ENER) and Joint Research Centre (JRC) presented their work on the supply of medical radioisotopes, with the focus on the SAMIRA initiative. In addition, the NMEu, the European Association of Nuclear Medicine and the International Atomic Energy Agency (IAEA) provided updates.

In September, ESA presented the observatory's activities and the results of its June meeting to the Council Working Party on Atomic Questions. ESA also presented information on the 2020 supply disruptions for medical radioisotopes and the related mitigation measures taken by the observatory in response to the COVID-19 pandemic.

## Security of supply of nuclear materials for non-power use

In line with its strategic objective and the SAMIRA action plan, in 2021 ESA continued to scrutinise the security of supply of HEU and HALEU, which are required to produce medical radioisotopes and to fuel research reactors. These strategic materials are currently not produced in the European Union and must be imported from the United States of America or Russia.

In cooperation with the Member States concerned, ESA continued to assist with the supply of HEU to users who still need it until they convert to HALEU, in line with international nuclear security and non-proliferation commitments. In close cooperation with the Euratom Member States concerned, the Agency renewed for the next 5 years the memorandum of understanding with the US National Nuclear Security Administration (NNSA) for the exchange of HEU for European research reactors and medical radioisotope production facilities ([25]). Renewal of the memorandum of understanding in February 2021 was ESA's first deliverable under the SAMIRA action plan to support Europe's Beating Cancer Plan ([26]) (see section 3.3.2).

> The Agency renewed for the next 5 years the MoU with the US NNSA for the exchange of HEU for European research reactors until their conversion to LEU fuel is completed.

20 See Section 3.3.
21 http://www.consilium.europa.eu/en/council-eu/preparatory-bodies/working-party-atomic-questions/.
22 https://ec.europa.eu/health/preparedness_response/risk_management/hsc_fr.
23 Heads of Medicines Agencies: CMDh (hma.eu).
24 The SPOC network aims to improve information sharing between Member States, the EMA and the Commission on significant shortages of medicines and to coordinate actions to help prevent and manage them.
25 Originally signed in 2014.
26 https://ec.europa.eu/info/strategy/priorities-2019-2024/promoting-our-european-way-life/european-health-union/cancer-plan-europe_en.


The dedicated working group on HALEU was reinstated and in May 2021 the Advisory Committee adopted the terms of reference for a third mandate. The working group's objective is to respond to the EU's need for research reactor fuel and medical radioisotopes production by exploring industrial and commercial options to build a European capacity for producing LEU metal. Three meetings of the working group were held in 2021 and it was planned to present the outcome of the work to the ESA Advisory Committee in spring 2022.

## 1.2.5. Cooperation with stakeholders and partners

### Outreach activities

Throughout 2021, ESA pursued contacts with EU authorities, utilities, industry and nuclear organisations to further its objectives. It monitored market developments and demand in the EU and provided advice and follow-up to ensure appropriate application of the common supply policy.

The Agency also oversaw the security and sustainability of the supply of medical radioisotopes in the EU, including through the co-chairmanship of the European Observatory on the Supply of Medical Radioisotopes. In this context ESA established further contacts, including for instance the EMA and its national SPOC network.

ESA responded to queries about the UK's withdrawal from the EU and Euratom, which came from individuals or businesses with commercial relations with companies in the UK.

In December, ESA became a corporate member of the European Nuclear Society (ENS) ([27]) - a learned society that brings together more than 12 000 professionals from the academic world, research centres, industry and authorities to exchange knowledge and experience about nuclear science and technology. Founded in 1975, the ENS is the largest society for nuclear science, research and industry in Europe.

### International cooperation

The Agency has long-standing and well-established relationships on nuclear energy with two major international organisations: the IAEA and the OECD NEA. In 2021, ESA continued to cooperate with these organisations by participating in working groups.

The joint NEA/IAEA uranium group is responsible for publishing the biennial report 'Uranium resources, production and demand' (known as the 'Red Book') ([28]), to which ESA contributes its analysis of supply and demand for nuclear fuel in the EU. The report provides up-to-date information on established uranium production centres and mine development plans as well as projections of nuclear generating capacity and reactor-related requirements.

The NEA expert group on uranium mining and economic development analyses uranium mining's potential contribution to economic and social development and explores whether uranium activities are managed in a way that benefits local and national economies. The expert group examines case studies in various countries to understand how uranium mining affects economic development, jobs, infrastructure, education and medical care ([29]). ESA contributes to these investigations and analyses.

In July, ESA joined the IAEA expert group. The aim is to create a technical document on global secondary uranium supplies. The group also holds consultative meetings with representatives of international agencies and industry. The group is using publicly available information to develop a document that would provide a general overview of secondary uranium supplies, organised and presented in a way that would be useful for Member States and, in particular, for those not familiar with secondary supplies.

27 https://www.euronuclear.org/.
28 https://www.oecd-nea.org/jcms/pl_52718/uranium-2020-resources-production-and-demand.
29 https://www.oecd-nea.org/jcms/pl_28160/expert-group-on-uranium-mining-and-economic-development-umed.

# 2. ESA analysis of supply and demand of nuclear material and services in the EU

**2021-JHR rack**


©CEA

In 2021, 106 commercial nuclear power reactors were operating in 13 Member States.

This overview of nuclear fuel supply and demand in the EU is based on information that the utilities or their procurement organisations provided in an annual survey covering:

- acquisition prices for natural uranium;
- the amounts of fuel loaded into reactors;
- estimates of future fuel requirements;
- quantities and origins of natural uranium, conversion services and separative work;
- future contracted deliveries; and
- inventory trends.

At the end of 2021, 106 commercial nuclear power reactors were operating in 13 Member States and were being managed by 17 nuclear utilities. Reactors operating in the UK are no longer in this analysis. Four reactors were under construction in France, Slovakia, and Finland.

According to the latest available data published by the European Commission, the gross electricity generation from nuclear plants within the EU-28 in 2020 was stable at 683.5 TWh, accounting for 24.6% of total EU-27production ([30]).

Unless otherwise mentioned:

- data before 2021 refers to the 27 EU Member States (EU-27) and the UK;
- 2021 data, current analysis and estimates of future requirements refer to the EU-27 only.

## 2.1. Fuel loaded

In 2021, 2 197 tU (tonnes of raw uranium) of fresh fuel was loaded into commercial reactors. It was produced using 15 401 tU of natural uranium and 183 tU of reprocessed uranium as feed, enriched with 11 588 tSW.

The fuel loaded into EU reactors had an average enrichment assay of 4.11%, with 83% falling between 3.50% and 4.72%. The average tails assay was 0.22%, with over 80% falling between 0.18% and 0.26%.

MOX (mixed oxide) fuel was used in several reactors in France and the Netherlands. MOX fuel loaded into nuclear power plants (NPPs) in the EU contained 4 858 kg plutonium in 2021,

30 Eurostat Energy Statistics, 2020.

a 7% decrease from 2020. Use of MOX resulted in estimated savings of 439 tU and 311 tSW (see Annex 5).

The amount of natural uranium included in fuel loaded into reactors in 2021, including natural uranium feed, reprocessed uranium, and savings from MOX fuel, totalled 16 022 tU.

> The amount of natural uranium included in fuel loaded into reactors in 2021 totalled 16 022 tU.

Savings in natural uranium resulting from the use of MOX fuel together with reprocessed uranium give the amount of feed material (which otherwise would have to be used) coming from domestic secondary sources. All this provided about 4.0% of the EU's annual natural uranium requirements.

**Table 1. Natural uranium equivalent included in fuel loaded by source in 2021**

| Source | Quantities (tU) | Share (%) |
|---|---|---|
| Uranium originating outside the EU-27 | 15 380 | 96 |
| Indigenous sources ([1]) | 642 | 4 |
| Total annual requirements | 16 022 | 100 |

*(1) includes reprocessed uranium, savings from the usage of MOX fuel, small quantities of underfed material, re-enriched tails or uranium of EU origin*

### Reprocessing of spent fuel

It is up to the Member States and their corresponding national policies whether they opt to consider the spent fuel as radioactive waste or as a valuable source of new material after reprocessing. According to European Commission data ([31]), 7 Member States out of 27 had reprocessed spent fuel or chosen the reprocessing option, and 2 Member States are keeping that possibility open.

### Plutonium and MOX fuel

MOX fuel is produced by mixing plutonium recovered from spent fuel and depleted uranium obtained from the enrichment process. Use of MOX fuel affects reactor performance and safety requirements. Reactors have to be adapted for this kind of fuel and must obtain a special licence before using it.

MOX fuel behaves similarly (though not identically) to the enriched uranium-based fuel used in most reactors. The main reasons for its use are the possibility of using plutonium recovered from spent fuel, non-proliferation concerns, and economic considerations. Reprocessing spent fuel and recycling recovered plutonium with uranium in MOX fuel increases the availability of nuclear material, reduces the need for enrichment services and contributes to security of supply.

## 2.2. Future requirements

EU utilities have estimated their gross reactor needs for natural uranium and enrichment services over the next 20 years, considering possible changes in national policies or regulatory requirements that result in the construction of new units (only projects which already have a construction licence), lifetime extensions, the early retirement of reactors, phasing-out or decommissioning. Net requirements are calculated on the basis of gross reactor requirements, minus the savings obtained from planned uranium/plutonium recycling and inventory usage.

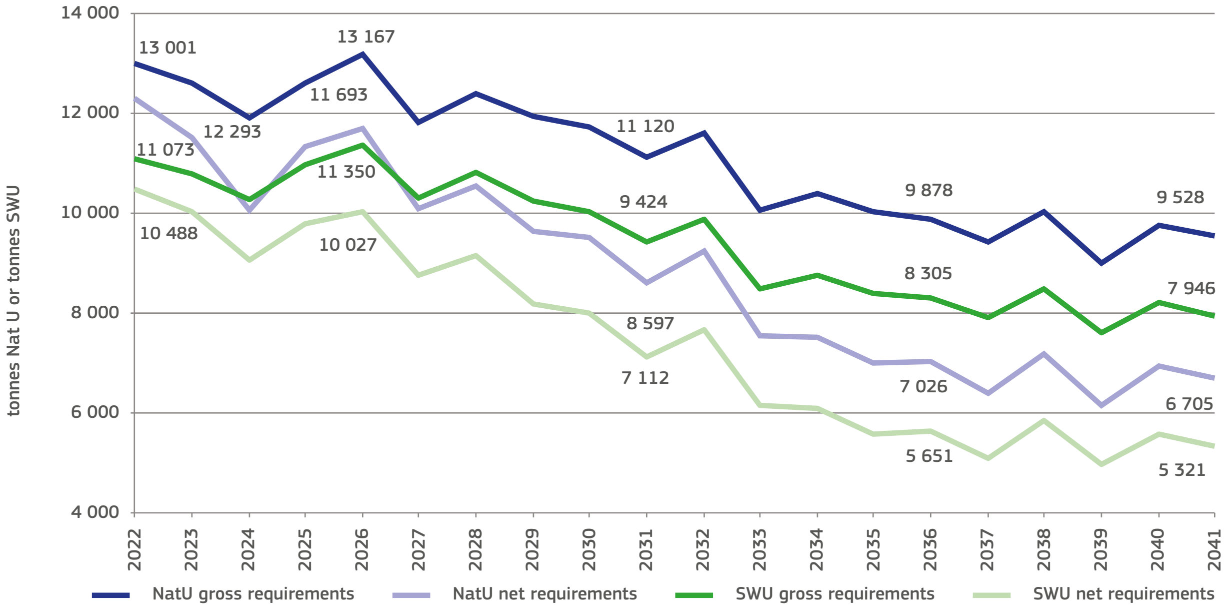
| Natural uranium — average reactor requirements | | |
|---|---|---|
| 2022-2031 | 12 223 tU/year (gross) | 10 528 tU/year (net) |
| 2032-2041 | 9 968 tU/year (gross) | 7 170 tU/year (net) |

| Enrichment services — average reactor requirements | | |
|---|---|---|
| 2022-2031 | 10 522 tSW/year (gross) | 9 060 tSW/year (net) |
| 2032-2041 | 8 391 tSW/year (gross) | 5 795 tSW/year (net) |

Estimates of future reactor requirements for uranium and separative work (SW), based on data supplied by all EU utilities, are shown in Figure 1 (see Annex 1 for numerical values).

31 Report from the Commission to the Council and the European Parliament on progress of implementation of Council Directive 2011/70/EURATOM and an inventory of radioactive waste and spent fuel present in the Community's territory and the future prospects, Seecond report, COM/2019/632 final

**Figure 1. Reactor requirements for uranium and separative work in the EU (in tonnes NatU or SWU)**




# 2.3. Supply of natural uranium

## Conclusion of contracts

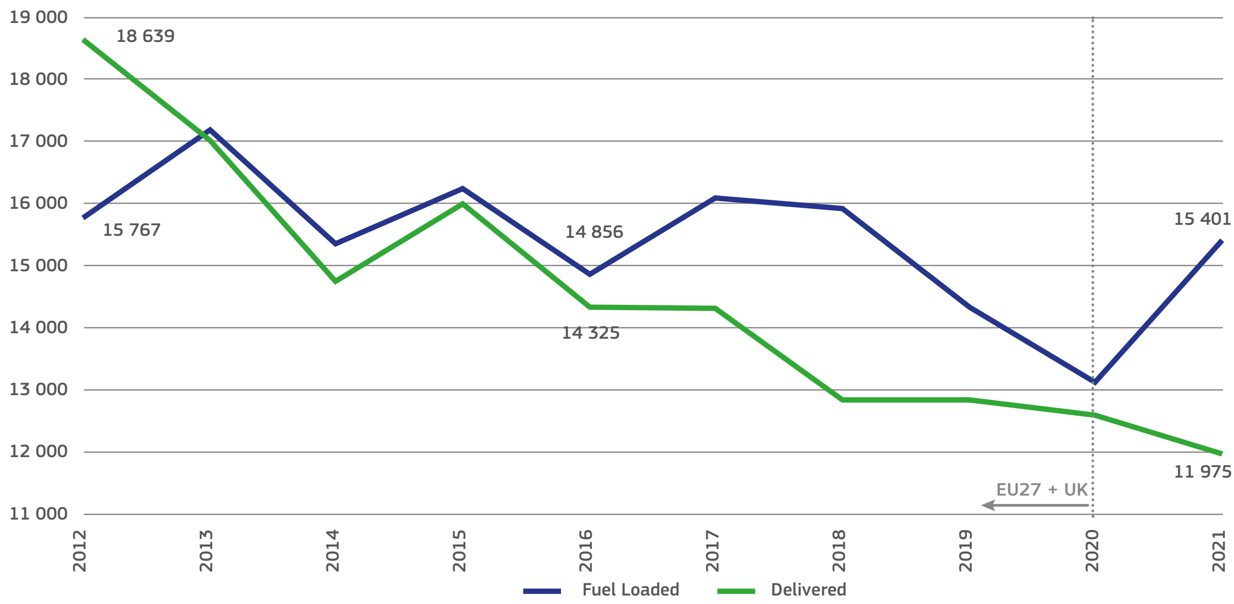
In 2021, ESA processed a total of 69 natural uranium contracts and amendments to contracts, of which 27 were newly concluded and registered. Of 23 new purchase/sale contracts, 15 involved EU utilities, and the remainder were signed by EU intermediaries or producers. Table 2 gives further details of the types of supply, terms and parties involved.

**Table 2. Natural uranium contracts concluded by ESA (including feed contained in EUP purchases)**

| Type of contract | Number of contracts concluded in 2021 | Number of contracts concluded in 2020 |
|---|---|---|
| **Purchase/sale by EU utilities/end users** | **15** | **22** |
| — multiannual (1) | 7 | 10 |
| — spot (1) | 8 | 12 |
| **Purchase/sale by EU intermediaries/producers** | **8** | **11** |
| — multiannual | 5 | 1 |
| — spot | 3 | 10 |
| **Exchanges and loans (2)** | **4** | **8** |
| **Amendments** | **42** | **35** |
| **TOTAL (3)** | **69** | **76** |

*(1) Multiannual contracts are contracts providing for deliveries extending over more than 12 months, whereas spot contracts provide either for a single delivery or for deliveries over a maximum of 12 months, whatever the time between conclusion of the contract and the first delivery.*
*(2) This category includes exchanges of ownership and exchanges of $U_3O_8$ against $UF_6$. Exchanges of safeguard obligation codes and international exchanges of safeguard obligations are not included.*
*(3) Transactions for small quantities (as under Article 74 of the Euratom Treaty) are not included.*

**Figure 2. Natural uranium equivalent feed contained in fuel loaded into EU reactors and natural uranium equivalent delivered to utilities under purchasing contracts (tonnes NatU)**




## Volume of deliveries

The deliveries covered are those to EU utilities or their procurement organisations in 2021, excluding research reactors. The natural uranium equivalent contained in enriched uranium purchases, when stated, is also taken into account.

In 2021, demand for natural uranium in the EU represented approximately 18% of global uranium requirements. EU utilities purchased a total of 11 975 tU in 117 deliveries under multiannual and spot contracts.

As in previous years, supplies under multiannual contracts constituted the main source for meeting demand in the EU. Deliveries of natural uranium to EU utilities under multiannual contracts accounted for 11 496 tU (of which 10 432 tU with reported prices) or 96% of total deliveries, whereas the remaining 4% (479 tU) was purchased under spot contracts.

On average, the quantity of natural uranium delivered was 114 tU per delivery under multiannual contracts. Quantities of natural uranium delivered under spot contracts varied substantially, making it impossible to calculate a meaningful average.

Demand for natural uranium in the EU represented approximately 18% of global uranium requirements.

Natural uranium contained in the fuel loaded into reactors in 2021 totalled 15 401 tU. For the past 8 consecutive years, EU utilities have been loading more material into reactors than they have been buying, which has caused a steady drop in inventory levels.

Figure 2 shows the quantities of natural uranium feed contained in fuel loaded into EU reactors and natural uranium delivered to utilities under purchasing contracts (see Annex 2 for the corresponding table for 1980-2021).

For the past 8 consecutive years, EU utilities have been loading more material into reactors than they have been buying it, which has caused a steady drop in inventory levels.

## Average delivery prices

In the interests of market transparency, ESA publishes three EU natural uranium price indices annually. These are based only on deliveries made to EU utilities or their procurement organisations under natural uranium and enriched uranium purchasing contracts in which the price is stated.

The natural uranium delivery price stated in purchase contracts concluded in recent years (mainly for new multiannual contracts but also for a non-negligible percentage of the spot contracts) is generally agreed by using formulas based on uranium price and inflation indices.

ESA's price calculation method is based on converting the currency of the original contract prices into EUR per kg uranium (kgU) in the chemical form $U_3O_8$, using the average annual exchange rates published by the European Central Bank. The average prices are then calculated after weighting the prices paid by the quantities delivered under each contract. A detailed analysis is presented in Annex 8.

Since uranium is mostly traded in US dollars on the global market, fluctuations in the EUR/USD exchange rate influence the level of the price indices calculated. In 2021, the annual average ECB EUR/USD rate stood at 1.18.

To calculate a natural uranium price excluding the conversion cost whenever the latter was included but not specified, ESA applied a rigorously calculated average conversion price, based on reported conversion prices under multiannual contracts for natural uranium.

1. **ESA spot $U_3O_8$ price**: the weighted average of $U_3O_8$ prices paid by EU utilities for uranium delivered under spot contracts was calculated to be:

In 2021, the ESA $U_3O_8$ spot price was not calculated because there were not enough transactions with eligible prices (less than 3) to calculate the index.

2. **ESA multiannual $U_3O_8$ price:** the weighted average of $U_3O_8$ prices paid by EU utilities for uranium delivered under multiannual contracts was calculated to be:

| | |
|---|---|
| EUR 89.00/kgU contained in $U_3O_8$ | up 25% from EUR 71.37 /kgU in 2020 |
| USD 40.49/lb $U_3O_8$ | up 29% from USD 31.36 /lb $U_3O_8$ in 2020 |

3. **ESA 'MAC-3' multiannual $U_3O_8$ price:** the weighted average of $U_3O_8$ prices paid by EU utilities, only for multiannual contracts which were concluded or for which the pricing method was amended in the past 3 years and under which deliveries were made, was calculated to be:

| | |
|---|---|
| EUR 92.75/kgU contained in $U_3O_8$ | up 23% from EUR 75.51 /kgU in 2020 |
| USD 42.17 /lb $U_3O_8$ | up 27% from USD 33.17 /lb $U_3O_8$ in 2020 |

The ESA $U_3O_8$ spot price reflects the latest developments on the uranium market, as it is calculated from contracts providing either for a single delivery or for a number of deliveries over a twelve-month maximum period.

The ESA multiannual $U_3O_8$ price was EUR 89.00/kgU $U_3O_8$ (USD 40.49/lb $U_3O_8$).

The multiannual prices paid varied widely, with approximately 80% (assuming a normal distribution) falling within the range from EUR 58.56 to EUR 105.12 /kgU (from 26.64 USD to 47.82USD /lb $U_3O_8$).

Usually, multiannual prices trade at a premium to spot prices, as buyers are willing to pay a risk premium to lock in future prices. However, the ESA multiannual $U_3O_8$ price is not forward-looking. It is based on historical prices contracted under multiannual contracts, which are either fixed or calculated based on formulas indexing mainly uranium spot prices.

Spot prices are the most widely indexed prices in multiannual contracts. The ESA multiannual $U_3O_8$ price paid for uranium originating in countries belonging to the Commonwealth of Independent States (CIS) – namely Russia, Kazakhstan, and Uzbekistan – was 17% lower than the price for uranium of non-CIS origin.

The ESA MAC-3 multiannual $U_3O_8$ price was EUR 92.75/kgU $U_3O_8$ (USD 42.17/lb $U_3O_8$).

The data were spread across a wide range, with approximately 80% of prices reported as falling between EUR 57.51 and 97.07 EUR /kgU (USD 26.16 to USD 44.16/lb $U_3O_8$).

The ESA MAC-3 index takes into account only multiannual contracts signed recently (2019-2021) or older multiannual contracts for which the uranium pricing method was amended during the same period, thus incorporating current market conditions and providing insights into the future of the nuclear market. The ESA MAC-3 multiannual $U_3O_8$ price paid for uranium originating in CIS countries was 33% lower than the price for uranium of non-CIS origin.

Figures 3a and 3b show the ESA average prices for natural uranium since 2011. The corresponding data are presented in Annex 3.

The ESA multiannual $U_3O_8$ and MAC-3 multiannual $U_3O_8$ price paid for uranium originating in CIS was respectively lower than the price for uranium of non-CIS origin.

**Figure 3a. Average prices for natural uranium delivered under spot and multiannual contracts, 2012-2021 (EUR/kgU)**

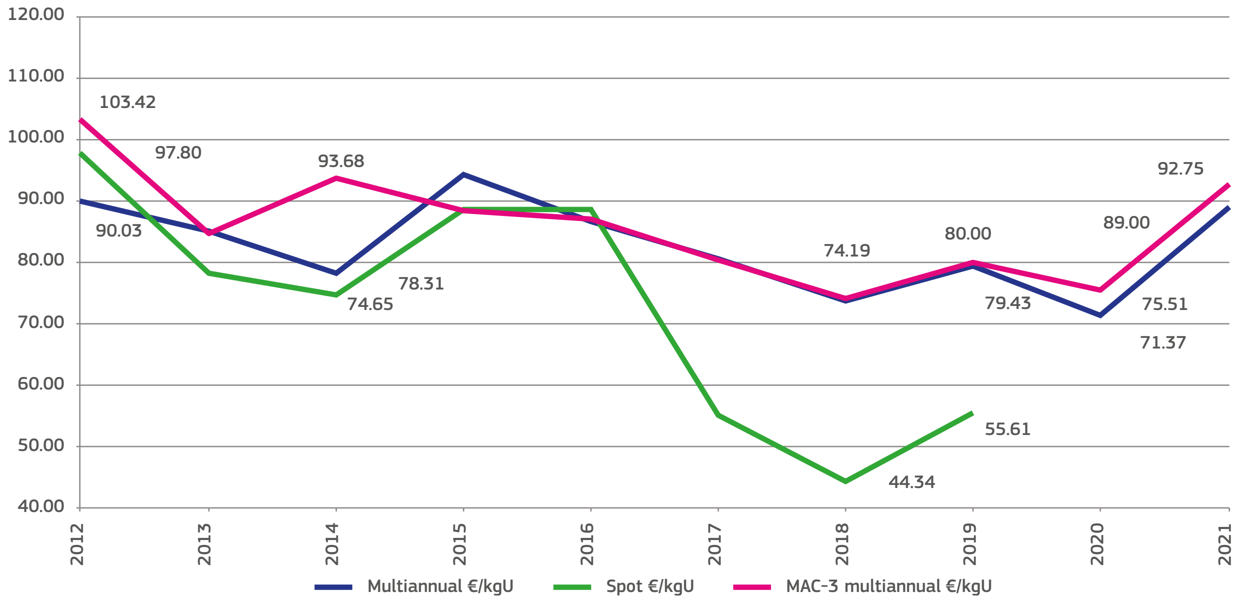
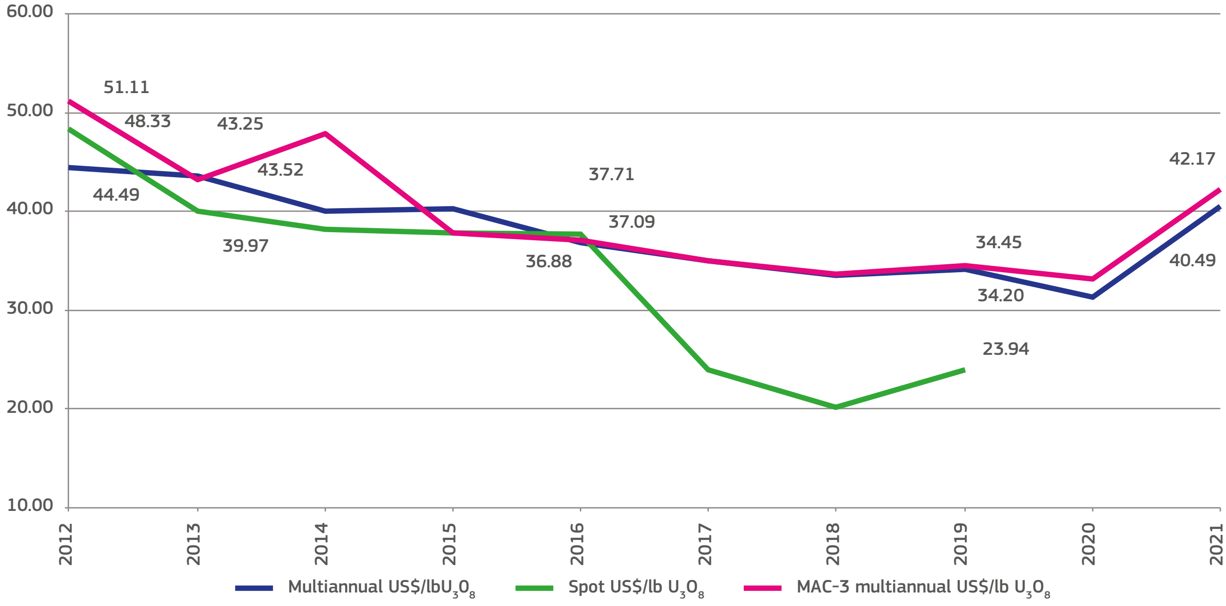


**Figure 3b. Average prices for natural uranium delivered under spot and multiannual contracts, 2012-2021 (USD/lb $U_3O_8$)**




## Origins

In 2021, natural uranium supplies to the EU continued to come from diverse sources. The origin of natural uranium supplied to EU utilities has remained similar to 2020, although there were some changes in market share.

**Table 3. Origins of uranium delivered to EU utilities in 2021 (tU)**

| Origin | Quantity | Share (%) | Change in quantities 2020/2021(2) (%) |
|---|---|---|---|
| **Niger** | 2 905 | 24.26 | 13.7 |
| **Kazakhstan** | 2 753 | 22.99 | -7.3 |
| **Russia** | 2 358 | 19.69 | 14.1 |
| **Australia** | 1 860 | 15.54 | 25.9 |
| **Canada** | 1 714 | 14.31 | 11.4 |
| **Re-enriched tails** | 196 | 1.64 | - |
| **Uzbekistan** | 162 | 1.36 | -50.6 |
| **EU** | 21 | 0.17 | -67.4 |
| **South Africa** | 5 | 0.04 | -78.2 |
| **Other (1)** | 17 | 0 | - |
| **Total** | **11 975** | **100.00** | |

*Because of rounding, totals may not add up.*

*(1) material saved through underfeeding, mixed origin and unknown*

*(2) 2020 includes EU27+UK*

Similarly to previous years, Niger, Kazakhstan and Russia were the top three countries delivering natural uranium to the EU in 2021, providing 66.94% of the total. Deliveries from Russia included purchases of natural uranium contained in enriched uranium products (EUP). In fourth place, uranium mined in Australia amounted to 15.54% of the total. Uranium from Canada accounted for 14.31% of the total. The five big producing countries provided more than 96% of all natural uranium supplied to the EU.

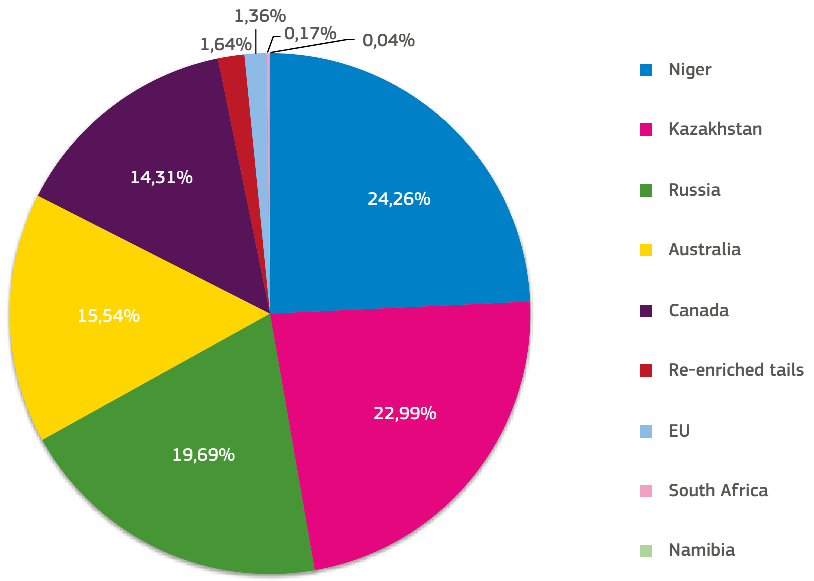
In terms of trends, deliveries of uranium from Canada increased by more than 11% and from Russia by 14%.

Natural uranium produced in CIS countries accounted for 5 470 tU (including re-enriched tails), or 45.68% of all natural uranium delivered to EU utilities, approximately the same level as the year before.

In contrast, deliveries of uranium from Africa continued to decrease to 2 833 tU, 99% of which came from Niger. The biggest drop was in figures for deliveries from South Africa, which was 78% down, and Namibia, with no deliveries. This was due to mines being placed on care and maintenance in several African countries in recent years, as well as ownership changes.

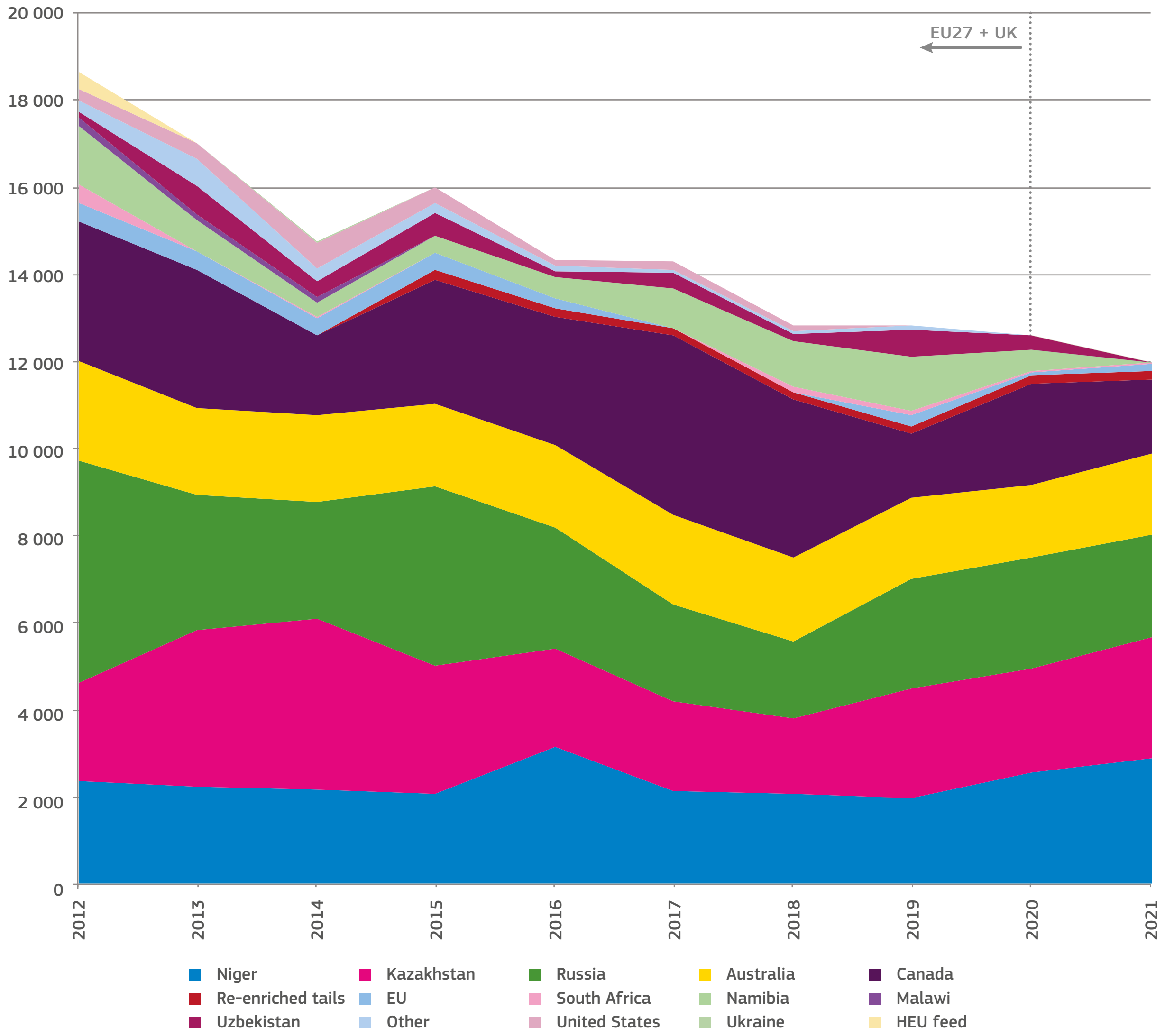
The five big producing countries provided more than 96% of all natural uranium supplied to the EU.

**Figure 4. Origins of uranium delivered to EU utilities in 2021 (% share)**




*Because of rounding, totals may not add up.*

**Figure 5. Purchases of natural uranium by EU utilities, by origin, 2012-2021 (tU)**




## Conversion services

During 2021, EU utilities, producers and intermediaries notified ESA of 14 new contracts to provide conversion services and 8 amendments to already notified conversion contracts.

Under separate conversion contracts, 8 138 tU were converted, accounting for 67% of all conversion service deliveries to EU utilities. The remaining 33%, or 3 999 tU, were delivered under contracts other than conversion contracts (purchases of natural $UF_6$, EUP, bundled contracts for fuel assemblies).

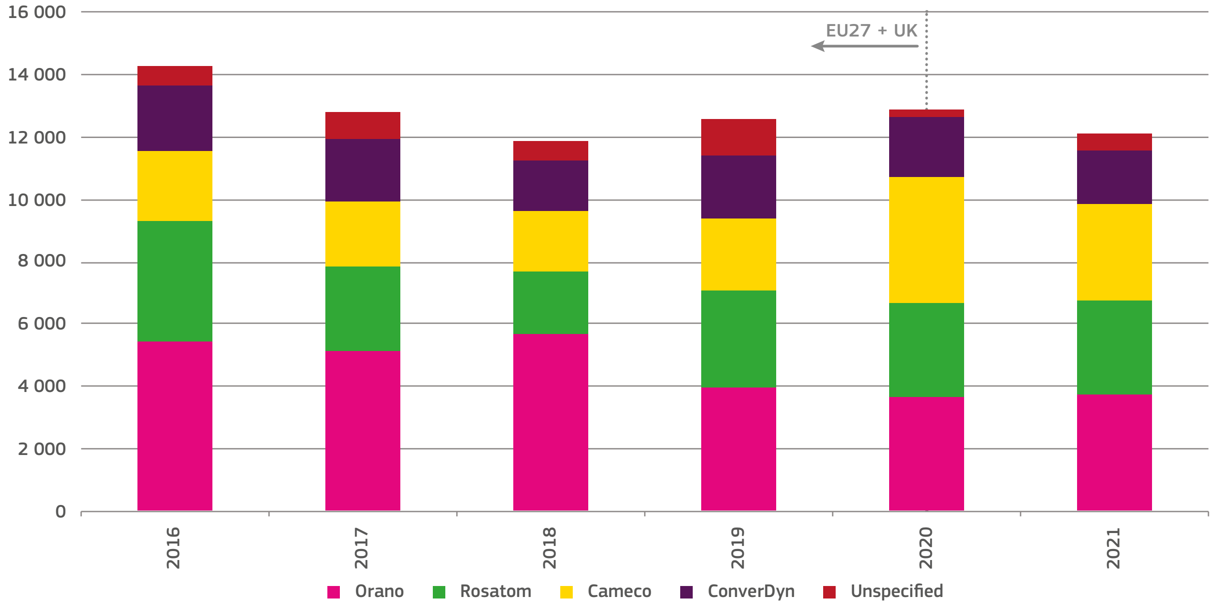
As regards the providers of conversion services, 31% of EU requirements were provided by Orano / Comurhex, followed by Cameco (25.5%), Rosatom (25%), and ConverDyn (14%).

### Table 4. Provision of conversion services to EU utilities

| Converter | Quantity in 2021 (tU) | Share in 2021 (%) | Quantity in 2020 (tU) | Share in 2020 (%) | Change in quantities 2020/2021 (%) |
|---|---|---|---|---|---|
| Orano (EU) | 3 723 | 30.67 | 3 651 | 28.41 | 2 |
| Cameco (Canada) | 3 095 | 25.50 | 3 993 | 31.07 | -22 |
| Rosatom (Russia) | 3 039 | 25.04 | 3 040 | 23.66 | - |
| ConverDyn (US) | 1 695 | 13.97 | 1 970 | 15.33 | -14 |
| Unspecified | 584 | 4.81 | 196 | 1.52 | 198 |
| **Total** | **12 137** | **100** | **12 850** | **100** | **-6** |

*Because of rounding, totals may not add up.*

### Figure 6. Supply of conversion services to EU utilities by provider, 2016-2021 (tU)



# 2.4. Special fissile material

### Conclusion of contracts

Table 5 shows the aggregate number of contracts, notifications, and amendments (32) relating to special fissile materials (enrichment services, enriched uranium, and plutonium) handled in 2020 and 2021 in accordance with ESA's procedures.

### Deliveries of low-enriched uranium

The enrichment services (separative work) provided to EU utilities in 2021 totalled 10 290 tSW, delivered in 1 569 tonnes of low-enriched uranium (tLEU), which contained the equivalent of 12 176 tonnes of natural uranium feed. In 2021, enrichment service deliveries to EU utilities were 8% lower compared to 2020, with NPP operators opting for an average enrichment assay of 4.22% and an average tails assay of 0.22%.

**Table 5. Special fissile material contracts concluded by or notified to ESA**

| Type of contract | Number of contracts concluded/ notifications acknowledged in 2021 | Number of contracts concluded/ notifications acknowledged in 2020 |
|---|---|---|
| **A. Special fissile materials** | | |
| **New contracts** | **29** | **25** |
| **Purchase (by an EU utility/end user)** | 5 | 7 |
| **Sale (by an EU utility/end user)** | 5 | 5 |
| **Purchase/sale (between two EU utilities/end users)** | 1 | 1 |
| **Purchase/sale (intermediaries/ producers)** | 0 | 4 |
| **Exchanges** | 0 | 6 |
| **Loans** | 1 | 2 |
| **Contract amendments** | **17** | **18** |
| **TOTAL (1)** | **29** | **43** |
| **B. Enrichment notifications (2)** | | |
| **New notifications** | **17** | **11** |
| **Notifications of amendments** | **26** | **19** |
| **TOTAL** | **43** | **30** |
| **Grand total** | **72** | **73** |

*(1) In addition, there were transactions involving small quantities (under Article 74 of the Euratom Treaty) which are not included here.*

*(2) Contracts with primary enrichers only.*

32 The aggregate number of amendments includes all the amendments to existing contracts processed by ESA, including technical amendments that do not necessarily lead to substantial changes in the terms of existing agreements.

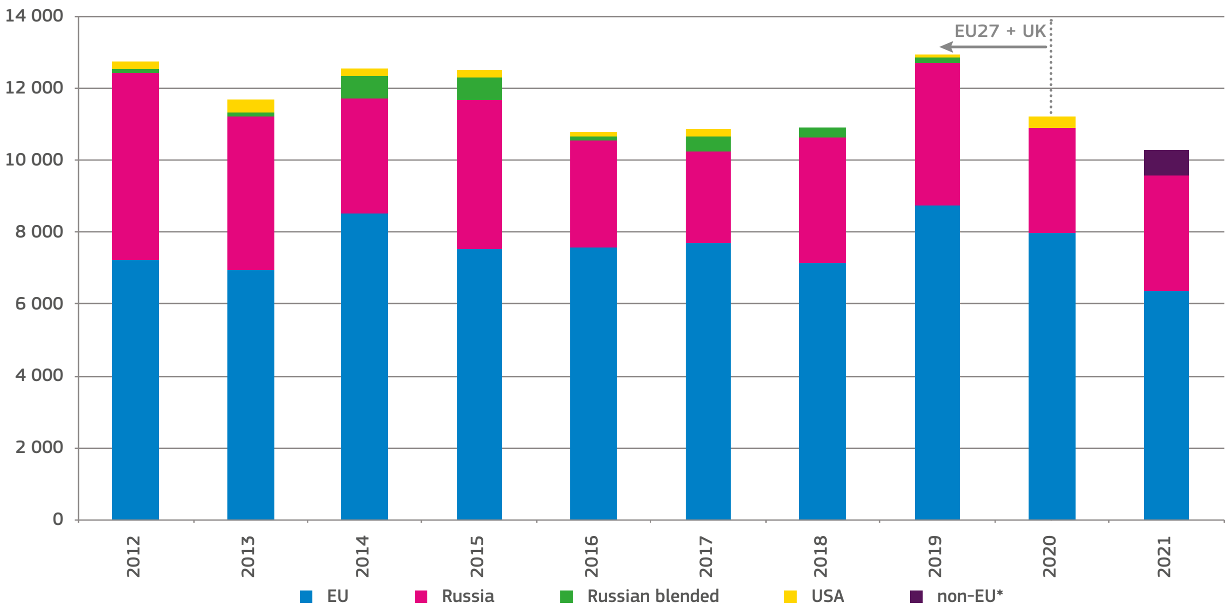
**Table 6. Origin of enrichment services to EU utilities in 2021**

| Enrichment origin | EUP (tU) | Uranium feed (tU) | Quantities (tSW) | Share (%) |
|---|---|---|---|---|
| **EU** | **978** | **7 428** | **6 385** | **62%** |
| **non-EU** | **561** | **4 748** | **3 905** | **38%** |
| *- of which Russia* | *465* | *3 854* | *3 190* | *31%* |
| **TOTAL** | **1 540** | **12 176** | **10 290** | **100%** |

The enrichment services in the EU (by Orano-GBII and Urenco) met 62% of EU requirements, totalling 6 385 tSW.

Deliveries of separative work from Russia (Tenex and TVEL) to EU utilities under purchasing contracts totalled 3 190 tSW, accounting for 31% of total deliveries. The aggregate total includes SWUs delivered under contracts concluded before joining the EU ('grandfathered' under Article 105 of the Euratom Treaty), which covered less than 4% of total EU requirements. No deliveries of downblended Russian highly enriched uranium were reported.

**Figure 7. Supply of enrichment to EU utilities by provider, 2012-2021 (tSW)**

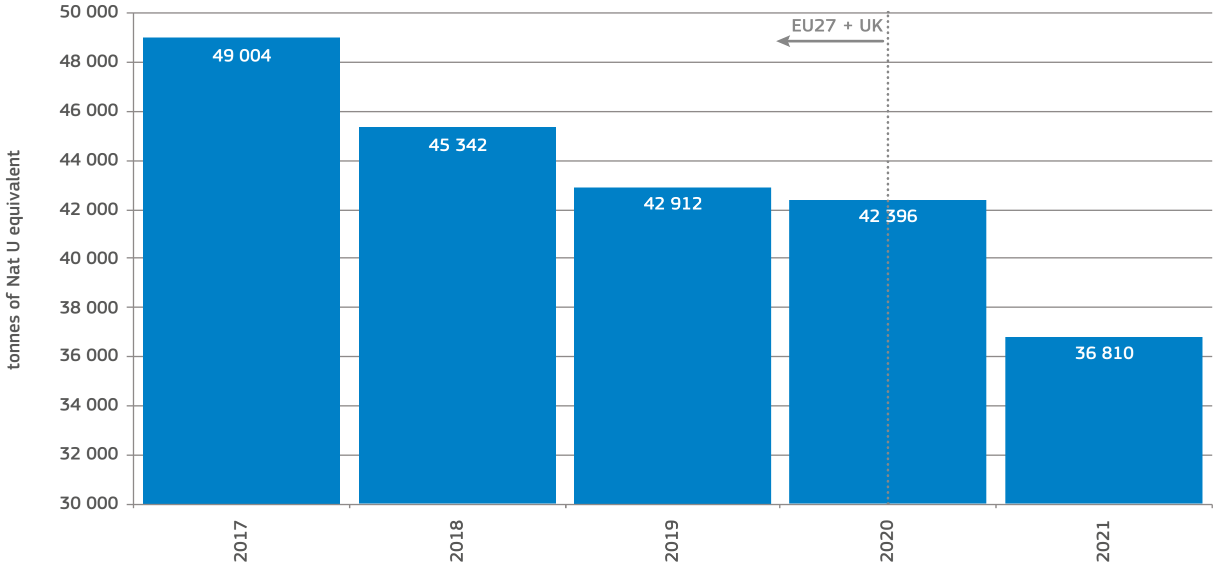



**non – EU – starting from 2021*

## Inventories

At the end of 2021, the natural uranium equivalent in inventories owned by EU utilities totalled 36 810 tU. The inventories represent uranium at different stages of the nuclear fuel cycle (natural uranium, in-process for conversion, enrichment, or fuel fabrication), stored at EU or other nuclear facilities.

**Figure 8. Total natural uranium equivalent inventories owned by EU utilities at the end of the year, 2017-2021 (in tonnes)**




The changes in the aggregate natural uranium inventories do not necessarily reflect the difference between the total natural uranium equivalent loaded into reactors and uranium delivered to EU utilities, as the level of inventories is subject to movements of loaned material, sales of uranium to third parties and one-off national transfers of material.

Based on average annual EU gross uranium reactor requirements (approximately 12 223 tU per year), uranium inventories can fuel EU utilities' nuclear power reactors for 3 years on average. However, the average conceals a wide range, although all utilities keep a sufficient quantity of inventories for at least one reload.

> Uranium inventories can fuel EU utilities' nuclear power reactors for 3 years on average.

## Future contractual coverage rate

$$\text{Contractual coverage rate of year X} = 100 \times \frac{\text{Maximum/and minimum contracted deliveries in year X}}{\text{Net reactor requirements in year X}}$$

The EU utilities' aggregate contractual coverage rate for a given year is calculated by dividing the maximum / and minimum contracted deliveries in that year – under already-signed contracts – by the utilities' estimated future net reactor requirements in the same year. The result is expressed as a percentage. Figure 9 shows the contractual coverage rate and minimum contractual coverage rate for natural uranium and SWUs, and Figure 10 shows the contractual coverage rate and minimum contractual coverage rate for conversion services for EU utilities.

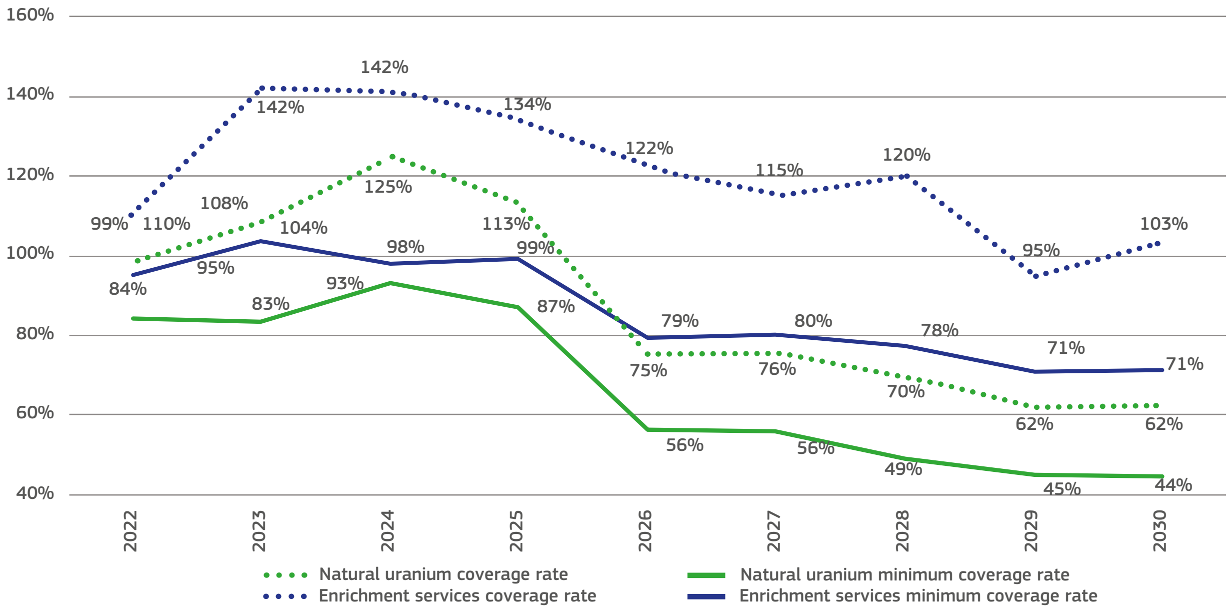
For net reactor requirements (the denominator), a distinction is made between demand for natural uranium and demand for enrichment services. Average net reactor requirements for 2022-2031 are estimated at 10 528 tU and 9 060 tSW per year (see table in Annex 1). ESA assumes the same quantity of requirements for conversion services as for natural uranium. A distinction is drawn between demand for conversion services covered under separate conversion contracts and other contracts, which include deliveries of natural $UF_6$, EUP or bundled contracts for fuel assemblies.

Quantitative analysis shows that EU utilities are well covered under existing contracts for both natural uranium and enrichment services. However, this situation changes when minimum contractual arrangements are calculated.

The supply of natural uranium is well secured from 2022 to 2025, with a contractual coverage rate of 99% in 2022 and 113% in 2025. In the long term, the uranium coverage rate drops to 62% in 2029 and stays at this level in 2030. As regards the uranium minimum contractual coverage rate, it fluctuates between 83% and 93% in 2022 and 2025 and then drops to 56% in 2026 to continue its slow decrease in 2028 and beyond. It ends at the level of 44% in 2030, which is the last year of the analysis.

The supply of enrichment services is well secured in the whole period of analysis. It is more than 100% until 2028 and drops to 95% in 2029. Concerning the enrichment services minimum contractual coverage rate, it oscillates in a range of 95% and 104% in 2022-2025, then it drops to 79% in 2026 and continues to stay at similar level until 2028. It decreases to 71% in 2029 and stays at this level until the end of the analysis.

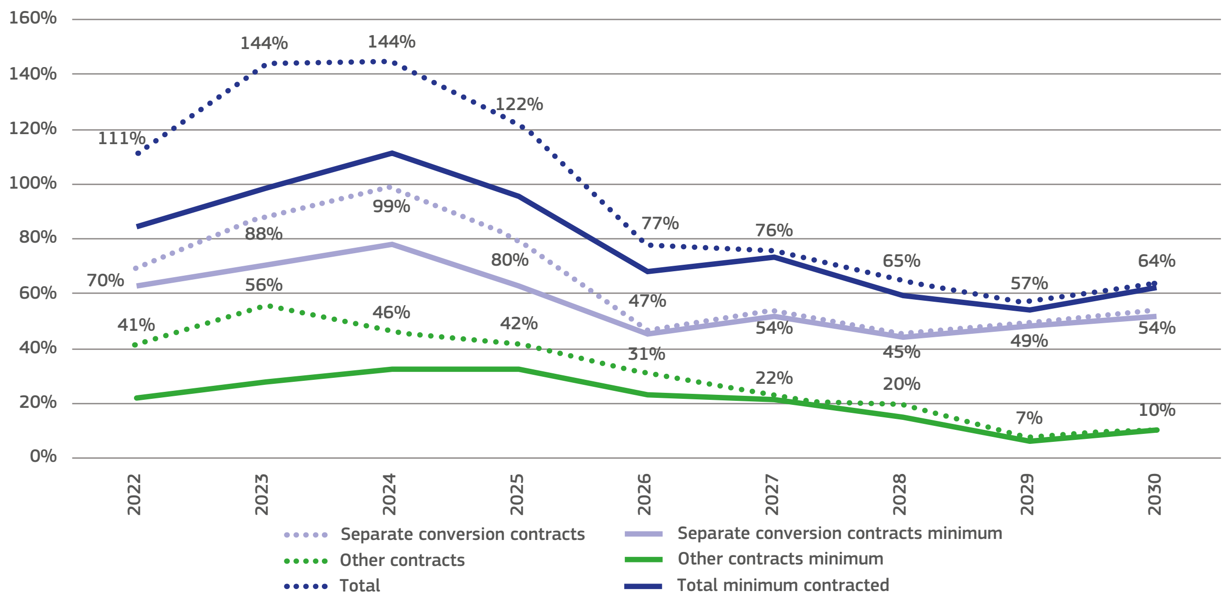
**Figure 9. Coverage rate for natural uranium and enrichment services, 2022-2030 (%)**




Quantitative analysis of conversion services shows that EU utilities' net reactor requirements are well covered under existing contracts, with conversion services coverage rates above 100% until 2025. Supply is well secured until 2030, which is the whole period of analysis, with a contractual coverage rate fluctuating between 57% and 77% in 2026-2030.

The picture looks different for minimum contractual coverage rate, which shows that minimum contracted supply of conversion services fluctuates between the level of 85% and 111% in 2022 and 2025, and between 54% and 73% in 2026 and 2030.

**Figure 10. Coverage rate for conversion services, 2022-2030 (%)**



## 2.5. Findings on the security of supply

Taking due account of nuclear safety and security requirements, which they have to comply with, nuclear power reactor operators are much concerned about the continuous availability of fuel and the prevention of supply disruptions. Key enabling factors for the long-term security of supply are to ensure that EU utilities have diverse sources of supply and do not depend excessively on any single design or supplier from a non-EU country, and to maintain the viability of EU industry at every stage of the fuel cycle.

As in other energy sectors, nuclear industry and power operators should seek to guarantee regular and sufficient supplies whatever the structure of the market for supplies. As outlined in ESA previous reports, various measures can be put in hand to reduce the risk of interruptions in supply or to limit their effects – such as diversified and unbundled contracts, the creation of emergency stocks, keeping reserves of production and transport facilities, etc. Contingency arrangements should be made to ensure operation of power plants as long as supply or market circumstances are seen not to be sufficiently stable, mindful of the current geopolitical and pandemic risks and their impact on the logistics and supply chain ([33]).

To fulfil its statutory mission of identifying market trends likely to affect the security of the EU's supply of nuclear materials and services, ESA continuously monitors the EU nuclear fuel market against world developments. The Agency has compiled comprehensive statistical reports on trends in the nuclear market on the basis of (i) data related to the contracts it concluded or acknowledged, (ii) information gathered from EU utilities in the annual survey at the end of 2020 and (iii) market data from other sources.

### Diversification and inventories

ESA has long recommended that utilities cover most of their current and future requirements under multiannual contracts from diverse sources of supply.

In line with this recommendation, deliveries of natural uranium to the EU under multiannual contracts accounted for 96% of total deliveries in 2021. As for mining origin, Niger, Kazakhstan, Russia, Australia and Canada together provided 96% of the natural uranium delivered to the EU, with the relative shares of individual producer countries varying slightly. Overall, deliveries of natural uranium to EU utilities are well diversified, but a number of utilities buy their natural uranium from only one supplier.

> Overall, deliveries of natural uranium to EU utilities are well diversified, but a number of utilities buy their natural uranium from only one supplier.

As for sources of supply of enriched uranium to EU utilities, 62% of enrichment services originated in the EU. The remaining services were provided by non-EU sources. Deliveries of separative work from Russia to EU utilities accounted for 31% of total deliveries, an 8% increase from the year before. Of these, contracts 'grandfathered' under Article 105 of the Euratom Treaty accounted for less than 4% of total deliveries.

ESA notes the positive aspects (notwithstanding certain limitations) of recycling materials obtained from reprocessing spent fuel. Re-enriched reprocessed uranium fuel was approximately the same level as in the previous year. MOX fuel loaded into NPPs in the EU resulted in estimated savings of 2.7% of all natural uranium loaded into the reactors in the EU.

Most EU utilities have access to at least two alternative fuel fabricators. In stark contrast with the situation elsewhere, the dependence on a single design and supplier of fuel for VVER reactors remains a significant vulnerability to the security of supply.

> Dependence on a single design and supplier of fuel for VVER reactors remains a significant vulnerability to the security of supply.

The Supply Agency notes the efforts by operators and producers to design, licence, create fabrication capacity and contract alternative fuel for VVER reactors.

Along with its recommendation that EU utilities maintain sufficient strategic inventories and use market opportunities to increase

33 European Commission, Directorate-General for Energy, Guevara Opinska, L., Gérard, F., Hoogland, O., et al., Study on the resilience of critical supply chains for energy security and clean energy transition during and after the COVID-19 crisis:final report, Publications Office, 2021, https://data.europa.eu/doi/10.2833/946002
European Commission, Directorate-General for Energy, Resilience of the nuclear sector in Europe in the face of pandemic risks:final report, Publications Office, 2022, https://data.europa.eu/doi/10.2833/902728

their stocks, depending on their individual circumstances, ESA finds that inventories remain at a healthy level for most utilities. However, it notes a steady decrease for at least 8 consecutive years, in parallel with decreasing needs. Although on average the inventory could fuel a utility for 3 years, this masks a wide range of coverage. Whether this inventory level is sufficient for a particular utility depends on its profile and risk factors.

### EU fuel cycle market and industrial set-up

Contrary to the global stagnation in uranium prices observed in previous years, 2021 was the year uranium prices started to rebound. After a quiet first eight months of 2021, the spot uranium price reached a nine-year high in September when it rose by over 60% in a couple of weeks.

The significant rise started in August, following several financial funds entering the market and starting to buy uranium. The price finally reduced slightly in the fourth quarter but stayed volatile until the end of year, oscillating around an average of 89 EUR/kgU. If such circumstances prevail in future, they may make way for necessary strategic investments.

Fleet requirements from Euratom Member States for the coming years are, on average, well covered by contractually secured supplies and services. Nevertheless, it is important to know that it may not be possible to execute all options in existing contracts from domestic suppliers to make up for deliveries from high risk suppliers.

A limited number of utilities remain contractually bound to single suppliers, often with clauses which impede unbundling. ESA considers that contracts bundling the sale of fuel assemblies with other transactions and/or conditions or stages (uranium, conversion, enrichment, fuel fabrication) in principle represent a vulnerability in security of supply.

Moreover, in the medium term, market access to conversion and enrichment services may be insufficient for the EU players, unless some plants ramp up production. The Supply Agency notes a continuous lack of sufficient investment in the fuel cycle, which is undermining long-term security of supply.

In the medium term, market access to conversion and enrichment services may be insufficient for the EU players, unless some plants ramp up production.

## 2.6. Recommendations on the security of supply

The regular and undisrupted supply of fuels, both for power and non-power applications of nuclear energy, is of paramount importance for Europe.

Nuclear power plants generate a quarter of all electricity in the EU, with this share amounting to more than 40% in several Member States (France, Slovakia, Hungary, Bulgaria). Furthermore, millions of Europeans are affected by diagnostic and therapeutic uses of ionising radiation each year. Hence, disruptions in supply would have dire consequences for households, hospitals, and industry. After safety, having a regular and undisrupted supply of fuel is a major concern for every nuclear power plant operator.

This report covers 2021, considering information, data and market trends pertaining to that year. However, the functioning of the nuclear market has been profoundly affected by the major geopolitical developments that have occurred in Europe since the end of the reporting period: Russia's invasion of Ukraine has massively disrupted the global supply system for all sources of energy. This has jeopardised trust in what had, previously, been a major nuclear energy partner, undermining the EU's security of supply for nuclear materials and services and aggravating dependence issues.

Russia's invasion of Ukraine has jeopardised trust in a major nuclear energy partner, undermining the EU's security of supply for nuclear materials and services and aggravating dependence issues.

As a reaction to the invasion, the EU has had to adopt far-reaching restrictive measures ([34]), hitting organisations, individuals and a number of activities, but also affecting transport and trade. Aware of the fact that the high amounts it pays for imports of energy resources from Russia help the latter sustain its war against Ukraine, the EU has decided

34 Council Regulation (EU) No 833/2014 of 31 July 2014 concerning restrictive measures in view of Russia's actions destabilising the situation in Ukraine, as amended many times (the current consolidated version as of 13.4.2022).

to phase out its dependence on Russia, which is significant in a number of sectors. Nuclear supplies, with all their specificities, will have to follow this move. The REPowerEU Plan ([35]) states:

'*Diversification options are also important for Member States currently dependent on Russia for nuclear fuel for their reactors serving either power generation or non-power uses. This requires working within the EU and with international partners to secure alternative sources of uranium and boosting the conversion, enrichment and fuel fabrication capacities available in Europe or in EU's global partners.*'

In the light of the above, ESA's recommendations in this Report will also take due account of the developments since 24 February 2022.

So far, nuclear fuel and services have been exempted from sanctions but the situation could evolve. Meanwhile, various challenges emerged to transportation routes from Russia and via Ukraine, and to the logistics of nuclear fuels in particular. Following the EU's restrictive measures against Russia, the air transportation route – chosen by some countries as a replacement for the railway route through Ukraine – is also available for a limited period, based on justified exceptions only[36].

Nuclear fuel and services have been exempted from sanctions, but the situation could evolve.

Existing fuel delivery through the Black Sea needs additional risk assessment, as it is affected by the war. Planned deliveries of Russian nuclear material and fuel may be further hindered by the continuous evolving situation and emerging concerns from carriers' refusal to transport, grant access to port or deal with Russian goods amid public sensitivity and/or reputational risks.

Ensuring security of supply from ore to nuclear fuel is a strategic objective of the Euratom Supply Agency. To that end, ESA monitors developments in the nuclear fuel market and in relevant technological fields in order to identify market trends that could affect the security of the EU's supply of nuclear materials and services.

Based on its analysis, ESA concludes that, in the medium and long term, EU utilities' demand for both natural uranium and for fuel fabrication and related services face an increased risk related to the Russian supply and connected to the new geopolitical situation. In fuel fabrication, the 100% reliance on a single design and supplier of VVER fuel remains a matter of highest concern, and it also leverages a supply of additional products and services from the same supplier.

Analysis from the nuclear industry (converters and enrichers) indicates that total open market conversion capacity may not be sufficient. Similarly, there is insufficient capacity to supply enrichment from the same open market sources, should the services from current non-open market players such as Russia not be available. Replacing the additional conversion and enrichment capacity could take several years. Industry investment would not be viable without some form of political and contractual commitment for the long term. Several Euratom Member States would oppose financial support from the Community in order to enhance security of supply.

Enrichment and conversion industry investments would not be viable without some form of political and contractual commitment for the long term.

The Agency puts forward the following recommendations for actions needed to address existing vulnerabilities.

## Overall recommendations

**Apply best practices in the field of security of supply.** On the matter of security of supply, Member states, utilities, industry and other users and market players are invited to take account of applicable best practices and recommendations, being mindful of possible inter-relationships across energy products and inter-dependencies of supply chains (e.g. origin of components and source material for components and parts, pandemic-related supply chains risks, etc.).

**Revise assessment of risk exposure.** Market players are advised to pursue market monitoring and contractual due diligence as a means of controlling their exposure to a changing market and averting security of supply vulnerabilities.

35 REPowerEU Plan: Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of Regions, adopted on 18.5.2022 – COM(2022) 230 final.

36 In March 2022, as a consequence of the restrictive measure, the European Union Aviation Safety Agency suspended the license of several air carriers, including carriers traditionally transporting nuclear fuels to the EU.

Market players are advised to pursue market monitoring and contractual due diligence as a means of controlling their exposure to a changing market and averting security of supply vulnerabilities

Risk factors pertinent to security of supply include, inter alia:

- legal and economic ownership;
- physical location of the nuclear materials and control over them;
- geographical origin, which may be different from customs origin;
- risk profile of transactions or commercial partners and suppliers;
- consequences of the evolving geopolitical situation.

**Revised risk preparedness.** In the light of recent events, identify early risks and establish alternative plans, reduce dependency on or replace high-risk-profile partners or operations/transactions (e.g. due to high-risk transport and complex logistics).

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**Establish long term diversified contracts.** Generally, multiannual contracts with diverse sources of supply are considered appropriate for utilities to cover most of their current and future requirements for uranium and services. Supply contracts concluded for a period longer than 10 years are possible with additional authorisations ([37]).

**Consider the risk of storage and transport.** All other conditions being equal, owners of nuclear fuels and related materials are invited to prefer physical storage and transportation at locations and by carriers in Euratom jurisdiction or in friendly jurisdictions, e.g. storage facilities on Member State territory.

**Create and maintain strategic stocks.** In respect of commercial, strategic and emergency stockpiling, Member States, producers and users are invited to take a coordinated rather than competitive approach, mindful of the special capital, financing and technical effort involved.

Public and private actors are encouraged to ensure timely investment in setting up facilities to support strategic management of source and special fissile material inventories, notably for enriched and other uranium products.

Inventories should be sufficient to stock fuel-fabrication-ready material to face short and mid-term lack of capacity following abrupt interruption of supply from existing partners/sources and until producers (converters, enrichers) could adapt.

**Monitor security of supply.** The security of supplies should be monitored at different levels: EU/Euratom, national and utility. This should be a coordinated effort to include all viewpoints and interests.

Energy regulators, safety regulatory, grid operators and electricity holdings should adequately factor in the nuclear supply risk into their risk assessment and preparedness. All parties concerned should cooperate to strengthen mechanisms for data and information sharing on the evolution of factors affecting the supply for nuclear fuels and relevant products.

**Maintain and advance technology.** Strategic industrial investment should be encouraged, especially in technologies.

Investment needs to be stepped up to adapt current industrial capacity to the market and to geopolitical developments, and to keep a minimum technological level and technical expertise in the front-end and back-end of the fuel cycle.

All options ought to be explored, to ensure the continued existence in the Euratom Community of (i) indigenous capacities for producing enriched uranium and (ii) of nuclear fuel designs, adequate to ensure a diversification of supply sources freely available to users in the Community. This should include also supply of HALEU for research reactors and radioisotopes.

**Maintain skills and knowledge management.** Further efforts are needed to make the nuclear sector (power and non-power use) attractive to skilled workers and young graduates.

**Support the single market for nuclear fuel.** Renewed consideration should be given to fully implementing the common nuclear market, by adopting appropriate measures to

37 Article 60 of the Euratom Treaty

underpin its efficiency. In that respect, increased cooperation between nuclear safety authorities in the individual Member States, in full mutual trust of implementing the highest safety standards, could facilitate licensing, inter alia, of alternative fuel designs and even pave the way for an alignment of the relevant norms, standards and procedures.

## Supply of material

**Keep diversified sources and look for widening.** Generally, multiannual contracts with diverse sources of supply are considered appropriate for utilities to cover most of their current and future requirements for uranium and services. Ideal security of supply means at least two alternative suppliers for each stage of the fuel cycle, and whenever possible at least one EU supplier.

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Due consideration ought to be given to geographical diversity and other aspects when deciding about the origin of the supplies, in the manner most appropriate to ensure that all users in the Community receive a regular and fair supply of ores and nuclear fuels

**Aerial view of enrichment facility Georges Besse II on the Tricastin nuclear site**

©Orano-COLIN MATHIEU

**Consider uranium prospecting and mining.** Prospecting for and exploiting mineral deposits for the benefit of users, in the Community domestically or in favourable jurisdictions, should be seriously considered, with due respect for sustainability aspects.

**Consider secondary sources.** To help offset the heavy dependence on external sources, all available solutions should be pursued to facilitate the production, circulation and use of alternative and recycled uranium and plutonium products, and thus promote a more circular nuclear economy.

Effort is needed in relation to the well-established approaches and technology for preserving natural resources, including reprocessing, uranium and plutonium recycling or the fast breeder option. This includes new investment, as well as the preservation and protection of research investment already made and knowledge already acquired by Euratom.

## Conversion and enrichment

**Contract now for long-term needs.** Long-term commitments are required to trigger investment that can enable increased conversion and enrichment capacity in the EU and/or in low-risk, reliable EU partner countries.

**Check if options are executable and under which conditions.** Restricted supply in the coming years may present material obstacles to executing additional supply options. Users are recommended to check their feasibility and under which conditions.

**Multilateral approach needed**. The EU, Euratom Member States, producers and users, could benefit from an international multilateral approach involving all countries concerned, to coordinate - rather than compete on - the phasing out of suppliers with a high risk profile. A multilateral approach could look at a joint assessment, possibly followed by an integrated and coordinated action plan to make available in particular the required conversion and enrichment capacity and to reach full independence, while avoiding shortages.

The EU, Euratom Member States, producers and users, could benefit from an international multilateral approach involving all countries concerned, to coordinate - rather than compete on - the phasing out of suppliers with a high risk profile.

**Fuel supply chain of reprocessed uranium.** Consider the viability of alternatives to the high-risk supply chain in this specific segment, including conversion, re-enrichment and pelletisation.

## Inventories

**Adequate inventories.** Utilities are advised to maintain – in low-risk locations (e.g. the EU) – sufficient inventories of nuclear materials to cover future requirements, and to use market opportunities to increase them.

Appropriate inventory levels should be maintained not only by utilities but also by producers, to forestall risks of shortages in the nuclear fuel supply chain.

In building up inventories, due care must be paid to determining the appropriate chemical-physical specifications and amounts, given the lead times in the fuel cycle steps involved. In particular, inventories should include fresh fuel in quantities that can respond to supply chain logistic delays or interruption. They should also include a number of reloads, to bridge until the availability of alternative fuel, in the event of definitive interruptions to the fuel supply that are dependent on a non-EU design and supplier.

> Fresh fuel inventories should include a number of reloads, to bridge until the availability of alternative fuel, in the event of definitive interruptions to the fuel supply that are dependent on a non-EU design and supplier.

**Net virtual inventories.** Those using dematerialised inventory management and contracting approaches, relying on third-party accounting systems or otherwise engaged in using holding accounts and book deliveries, are encouraged to periodically check that the accounts match the material reality.

## Fuel fabrication

**Diversify.** In due compliance with all requirements applicable, notably safety, the diversification of fuel should include:

- alternative designs, with ideally/preferably at least one based on European intellectual property rights,
- a diversified supply chain (services, components, fabrication capacity), in particular considering geographical/geopolitical risks,
- licensing and contracting of the alternative fuels,
- support for the emergence and licensing of an alternative design.

If the full-scale diversification is not viable for technical or economic reasons, users should compensate for this by other measures, including increased inventories of fuel assemblies.

**Diversification plans.** The utilities and research reactor operators that depend on a non-EU fuel design or supplier should develop and implement diversification plans, covering all diversification aspects and all steps in the process. Particular care should be given to accelerating the arrival on the market of alternative fuel design solutions for reactors presently bound to a single design from outside the EU, particularly reactors planned for long-term operation. They should cooperate with ESA and national authorities to jointly monitor the implementation of the plans and take action to forestall any risks or threats to their timely completion.

> ESA and national authorities should jointly monitor the implementation of fuel diversification plans of utilities and research reactor operators that depend on a non-EU fuel design or supplier and take action to forestall any risks or threats to their timely completion.

The utilities and research reactor operators that depend on a non-EU fuel design or supplier should develop and implement, accelerating the arrival on the market of alternative fuel design solutions

**Lead Test Assemblies (LTA) manufactured by Westinghouse (Electric Sweden AB) for the Temelín NPP**


©CEZ-MF

**Actively search for alternative solutions.** Operators of power and research reactors dependent on a single non-EU design of fuel assemblies and components should enable, engage in and employ alternative fuel design, while being mindful of suppliers, their origins and dependencies. They are advised to step up engagement with industry and cooperation with ESA and other players to bring about alternative solutions.

**Cooperation.** Cooperation between industry, operators and regulators is vital to reduce the time to design and market alternative nuclear fuel, furthering security of supply with safety at the fore. All options ought to be explored, to ensure the continued existence in the Community of indigenous capacities for designing and producing alternative fuel.

**Strategic fuel inventories.** While taking concrete action to encourage the emergence and employment of alternative designs or suppliers, utilities vulnerable at the fuel fabrication stage are advised to keep strategic inventories of source materials, or even of assembled fuel, and an appropriate number of reloads per reactor, depending on their exposure to security of supply risks.

**Open new build contracts.** Particular attention should be paid to investment in building new nuclear power plants in the EU using non-EU technology, to ensure that these plants are not dependent exclusively on a single non-EU design of nuclear fuel: any new investment has to be conditional on being able to diversify the fuel design. Contract terms must expressly provide for licensing and use of fuel assemblies from other suppliers, notably by providing for the disclosure of fuel compatibility data and for the testing of alternative fuel assemblies.

## Tendering and contractual aspects

**Planning tenders.** Planning their tenders, market players should carefully consider the selection criteria, so as to give due weight to the security of supply risks. They are invited to inform ESA about their tender plans and to seek opinion and advice on matters in the ESA remit, to facilitate the smooth conclusion of contracts.

Planning their tenders, market players should carefully consider the selection criteria, so as to give due weight to the security of supply risks.

**Technical data sharing.** Contracts for fuel supply must expressly provide for (i) sharing the relevant technical data, enabling suppliers to design alternative fuel and (ii) testing such fuel, so it can be licensed by the regulatory authorities.

**Unbundling options.** Parties engaging in contracts that bundle supplies of fuel assemblies with other transactions and/or conditions, potentially pertaining to various stages of the nuclear fuel cycle are advised to negotiate clauses providing for unbundled procurement and allowing them to have different suppliers in the various stages of the cycle, without facing any kind of penalties.

**Prices and financial terms.** Parties engaging in contracts with non-EU parties should be mindful of financial and payment terms. A careful approach is recommended, given possible future developments, such as excessive price volatility or unstable or unilateral currency exchange rates and inflation rates. Payment in EUR should be preferred.

**Force majeure.** Attention is drawn to the fact that “force majeure” may not be understood/interpreted in the same way by all contractual parties.

**Holding accounts.** Market players who rely on third-party contractual or holding account arrangements to hedge their supply security vulnerabilities are advised to take due account of potential geographical, political and other risks, while giving their agreement on fungibility, storage location and transportation clauses.

## Transport

**Alternative routes and modes of transport.** Users and producers should be mindful of transport risks and establish alternative routes and alternative modes of transport, taking into account origin and transit risks.

> Users and producers should be mindful of transport risks and establish alternative routes and alternative modes of transport, taking into account origin and transit risks.

**Carriers.** Industry, users and their associations should consider taking joint action to:

- inform carriers about the existing restrictive measures and the exemptions for nuclear fuel cycle transports;
- increase the set of available carriers of nuclear materials and fuels in the different transport means;
- make available an appropriate information source on EU and world carriers who are able to transport nuclear goods.

**Alignment.** Efforts should be continued to develop a uniform pan-European arrangement for handling cross-border transport package approvals that is valid in each country.

# 3. Overview of EU developments

## 3.1. Euratom

### 3.1.1. EU nuclear energy policy

2021 was an important year for energy policy, which is at the centre of the European Green Deal ([38]). Despite the challenges posed by the pandemic and a major electricity and gas price crisis, the EU delivered several key pieces of legislation in the energy sector to support the Green Deal's objectives.

One piece of legislation was on the EU's ongoing assistance to Bulgaria, Lithuania and Slovakia in the decommissioning of their nuclear reactors. The EU's support in this matter, decided when these countries joined the EU, was reiterated by the adoption of two new Council Regulations to ensure continued EU funding for the Nuclear Decommissioning Assistance Programmes for 2021-2027. The budget allocates EUR 63 million to Bulgaria, EUR 552 million to Lithuania and EUR 55 million to Slovakia. In Bohunice (Slovakia) and Kozloduy (Bulgaria) the decommissioning operations are scheduled to finish by the end of 2027 and 2030 respectively. The decommissioning of the Ignalina nuclear power plant (NPP) in Lithuania is scheduled to last until 2038. Under these programmes, synergies and efficiencies are sought to minimise risks and costs (e.g. benefiting from the similar designs of the Kozloduy and Bohunice NPPs), as well as to maximise the benefits brought by pooling experience, methods and tools. In addition, the programmes have started helping share knowledge across the EU.

Another legislative act is related to the "EU taxonomy" ([39]) - a tool for classifying environmentally sustainable economic activities and for directing more investments towards them. On 2 February 2022, the Commission approved in principle a Complementary Taxonomy Delegated Act ([40]), which classifies - under strict conditions - certain fossil gas and nuclear energy activities as transitional activities contributing to climate change mitigation. The Delegated Act builds on a dedicated in-depth scientific assessment of the nuclear energy, initially carried out by the Joint Research Centre, the in-house science and knowledge service of the Commission, whose Report was published ([41]) and further reviewed by two sets of experts, the "Group of Experts on radiation protection and waste management under Article 31 of the Euratom Treaty" ([42]), as well as the "Scientific Committee on Health, Environmental and Emerging Risks" ([43]) on environmental impacts ([44])([45]).

The European Commission approved in principle a Complementary Taxonomy Delegated Act, which classifies - under strict conditions - certain fossil gas and nuclear energy activities as transitional activities contributing to climate change mitigation.

38 COM(2019) 640 final.
39 Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088 OJ L 198, 22.6.2020, p. 13–43
40 C(2022) 631
41 EUR 30777 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-40538-2, doi:10.2760/207251, JRC125953.
42 https://energy.ec.europa.eu/topics/nuclear-energy/radiation-protection/scientific-seminars-and-publications/group-experts_en
43 https://ec.europa.eu/health/scientific_committees/scheer_en
44 These reviews are accessible at https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/eu-taxonomy-sustainable-activities_en#nuclear
45 The Complementary Taxonomy Delegated Act will enter into force and apply as of 1 January 2023, if neither of the co-legislators vetoes it. By its resolution of 6 July 2022 (https://www.europarl.europa.eu/news/en/press-room/20220701IPR34365/taxonomy-meps-do-not-object-to-inclusion-of-gas-and-nuclear-activities), the European Parliament decided not to object the Act.

As one of its main tasks under the Euratom Treaty, in 2021 the Commission continued to monitor the complete transposition and the effective implementation of the Euratom legal framework for nuclear safety, radiation protection and radioactive waste management. This concerned, in particular, the amended Nuclear Safety Directive ([46]), the Basic Safety Standards Directive ([47]), the Euratom Drinking Water Directive ([48]), the Radioactive Waste Management Directive ([49]), and the Shipments of Radioactive Waste Directive ([50]).

The Commission prepared its second progress report to the European Parliament and the Council on the implementation of the amended Nuclear Safety Directive, based on national reports received in 2020. This report is expected to be adopted in 2022. In addition, to organise the topical peer reviews (TPRs) required by the amended Nuclear Safety Directive, the Commission maintained its close cooperation with Member States' regulatory authorities in the European Nuclear Safety Regulators Group (Ensreg). They worked together on the follow-up of the first TPR on managing the ageing of nuclear reactors, and on the timely preparation of the second TPR on fire protection at nuclear installations. The Commission discussed these issues with a number of Member States and started reviewing national reports of all Member States on the implementation of the Radioactive Waste Management Directive.

The Commission set up a group of experts on the financial aspects of nuclear decommissioning and spent fuel and radioactive waste management and set out the scope of its work. The Commission also continued to cooperate with the IAEA on the international peer reviews of Member States' national frameworks and regulatory authorities, as required by the amended Nuclear Safety Directive and the Radioactive Waste Management Directive respectively. Under the Shipments of Radioactive Waste Directive and on the basis of the national reports received, the Commission prepared its fourth report to the European Parliament and the Council on the implementation of the Directive. This is expected to be adopted in 2022. On implementation, in 2021 the Commission continued to pursue infringements of the Basic Safety Standards Directive and of the Euratom Drinking Water Directive by those Member States that did not completely or correctly transpose the Directives.

Following the European Court of Auditors' Special Report 03/2020 ([51]) which concluded that the Commission has contributed well to nuclear safety in the EU, in 2021 the Commission worked towards putting into practice the three recommendations for further improvement.

In the field of nuclear emergency preparedness and response, the Commission ensured the continuous operation of the European Community Urgent Radiological Information Exchange (Ecurie) to exchange urgent information in the event of a radiological emergency, and of the European Radiological Data Exchange Platform (Eurdep) for the exchange of radiation monitoring data. The Commission also worked towards the participation of non-EU Member States in the Ecurie and Eurdep systems. In particular, the the Ecurie system was extended to Bosnia and Herzegovina.

In June 2021, the Commission organised the first EU Workshop on Small Modular Reactors (SMRs). One of the major outcomes of this workshop was the proposal from stakeholders to create a European SMR partnership to encourage cooperation between all stakeholders, including the commercial sector and technical safety organisations.

The Commission continued to cooperate with various stakeholders in the nuclear field. For instance, in January 2021, the Commission, together with Nuclear Transparency Watch, held a European roundtable on information and public participation in the field of radioactive waste management. The roundtable acted as a waypoint on the implementation of the Aarhus Convention ([52]) in the area of radioactive waste management at European level. It focused, in particular, on the implementation of the Radioactive Waste Directive transparency provisions and on the important issue of public access to research and expertise.

At international level, one of the main achievements was the adoption of administrative arrangements to implement the nuclear cooperation agreement with the United Kingdom on the safe and peaceful uses of nuclear energy, which will be the basis for developing bilateral energy relations. More detailed information is provided under section 3.1.6.

The Commission engaged in strengthening nuclear safety globally through close collaboration with international organisations and neighbouring non-EU countries, such as

46 Council Directive 2014/87/Euratom of 8 July 2014 amending Directive 2009/71/Euratom establishing a Community framework for the nuclear safety of nuclear installations, OJ L 219, 25.7.2014, pp. 42–52.
47 Council Directive 2013/59/Euratom of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom, OJ L 13, 17.1.2014, pp. 1–73.
48 Council Directive 2013/51/Euratom of 22 October 2013 laying down requirements for the protection of the health of the general public with regard to radioactive substances in water intended for human consumption, OJ L 296, 7.11.2013, pp. 12–21.
49 Council Directive 2011/70/Euratom of 19 July 2011 establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste, OJ L 199, 2.8.2011, pp. 48–56.
50 Council Directive 2006/117/Euratom of 20 November 2006 on the supervision and control of shipments of radioactive waste and spent fuel, OJ L 337, 5.12.2006, pp. 21–32.
51 Special Report 03/2020: The Commission contributes to nuclear safety in the EU, but updates required (europa.eu), published in February 2020.
52 Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters done at Aarhus, Denmark, on 25 June 1998.

Belarus, Turkey and Ukraine. In 2021, one of the Commission's priorities was to follow up, in cooperation with Ensreg, the peer review of Belarus' national action plan, and the implementation of stress tests recommendations for the Belarusian nuclear power plant (NPP) in Astravyets. Ensreg and the Commission organised two on-site visits to the plant, and the reports of these visits were approved by Ensreg. Following the completion of the Astravyets peer review process, preparations began for the stress tests to be carried out on the Akkuyu project in Turkey.

Work continued on strengthening the Commission's cooperation with third parties through nuclear cooperation agreements. The South Africa-Euratom nuclear cooperation agreement was ratified by South Africa and entered into force in 2021. The Commission has started to engage with the South African authorities on the practical application of the agreement.

The South Africa-Euratom nuclear cooperation agreement was ratified by South Africa and entered into force in 2021.

The Commission also aims to give people in the EU better access to high-quality radiological and nuclear technologies in medicine, while respecting the highest safety standards. Further information is provided under section 3.3.2.

Finally, the Commission's Directorate-General for Energy contributes to the development of fusion energy technologies through the ITER project. More information is provided under section 3.1.3.

## 3.1.2. Euratom safeguards

Euratom safeguards are the nuclear material supervision system under the exclusive competence of the Commission. The Directorate-General for Energy is the Commission department responsible for Euratom safeguards, which it implements through a set of verification activities to ensure that in the EU nuclear materials are not diverted from their intended peaceful use. For international suppliers of nuclear material to the EU, Euratom safeguards offer a guarantee that nuclear materials are being used appropriately and peacefully in the EU.

In 2021, the Commission continued to prioritise its safeguards activities by applying state-of-the-art techniques, which reflect developments in nuclear and information technology associated with the changing political and social environment and the related safeguards challenges.

The Commission continued to work in close cooperation with the IAEA on fostering the joint use of common safeguards equipment and on the implementation of the 'safeguards by design' concept, which integrates relevant safeguards considerations into the design phase of nuclear installations.

Despite the still challenging situation during the second year of the COVID-19 pandemic, the Commission was able to fulfil all the international safeguards obligations entered into under multilateral agreements with the IAEA, as well as under bilateral agreements with non-EU countries. In 2021, 99.95% of all nuclear materials under Euratom safeguards were verified, a return to the pre-pandemic level. The Commission did not detect any case of nuclear material diversion.

Despite the still challenging situation during the second year of the COVID-19 pandemic, the Commission was able to fulfil all the international safeguards obligations entered into under multilateral agreements with the IAEA, as well as under bilateral agreements with non-EU countries.

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Following the withdrawal of the United Kingdom from the EU, the bilateral agreement between the UK and Euratom for cooperation on the safe and peaceful uses of nuclear energy ([53]) was implemented provisionally from 1 January 2021 and formally from 1 May 2021. The Commission Decision of 22 December 2021 adopted internal administrative arrangements to implement the UK-Euratom agreement.

The Commission also adopted in July 2021 a Staff Working Document on the revised implementation of Euratom treaty safeguards.

Finally, the Commission launched an evaluation of Commission Regulation (Euratom) No 302/2005 on the application of Euratom safeguards, in view of its possible revision in the future.

## 3.1.3. ITER and the Broader Approach

Throughout 2021, the Directorate-General for Energy supported the construction of ITER (the International Thermonuclear Experimental Reactor) and the development of fusion energy.

At the end of 2021, ITER's construction work on 'first plasma' was 75.8% complete. When fully completed, it will be possible to begin the first experiments. In practical terms, the civil engineering works of the tokamak building and the first European toroidal magnets have been completed and the first poloidal magnets have been tested. However, the European sectors of the vacuum vessel are still to be delivered and are experiencing significant difficulties and delays. In addition to the first-of-a-kind challenges inherent to the project, the COVID-19 pandemic affected its progress in 2021 and caused some additional delays. The ITER Organization and the ITER members are analysing the impact of the pandemic and of the late delivery of some components and have agreed to update the baseline, the first elements of which will be presented in spring 2022.

At the end of 2021, ITER's construction work on 'first plasma' was 75.8% complete.

In 2021, following the launch of the second phase of activities of the broader approach, Euratom and Japan started using the facilities that have been built and have been working closely with ITER, particularly on the assembly phase. Japan and Euratom have also been testing and commissioning the JT-60SA tokamak in Naka in preparation for its first plasma, planned for the second half of 2022. This device is the largest and most modern tokamak in the world and will remain so until ITER is completed.

53 Published in the *Official Journal of the EU* on 31 December 2020.

The EU decided to allocate EUR 5.61 billion to the ITER project for 2021-2027, following the adoption of a Council decision in February 2021.

## 3.1.4. The Commission's research and innovation programmes

The Euratom research and training programme (2021-2025) complements Horizon Europe, which covers nuclear research and innovation. It uses the same instruments and rules of participation as Horizon Europe.

On 12 May 2021, the Council adopted the Regulation establishing the Euratom research and training programme for 2021-2025 ([54]).

> The Euratom research and training programme for 2021-2025 has a budget of EUR 1 382 million and will contribute to fusion and fission research, support Europe's Beating Cancer Plan and strengthen Europe's nuclear expertise and competence.

The programme has a budget of EUR 1 382 million and will contribute to fusion and fission research, support Europe's Beating Cancer Plan and strengthen Europe's nuclear expertise and competence

The aim of the regulation is to pursue nuclear research and training activities with an emphasis on the continuous improvement of nuclear safety, security and radiation protection, as well as to complement Horizon Europe's objectives.

The objectives of the 2021-2025 programme represent have evolved compared to previous Euratom programmes. Some priorities are changing with the evolving needs of the EU and its Member States. The new programme will pursue the previous programme's key research activities (nuclear safety, radioactive waste and spent fuel management, radiation protection and fusion energy), but it will expand research into non-power applications of ionising radiation and make improvements in the areas of education, training and access to research infrastructures.

The Euratom programme puts a strong emphasis on developing nuclear skills and competence. It will support the mobility of researchers in the nuclear field under Horizon Europe's Marie Skłodowska-Curie Actions (MSCA).

On 1 July, the Commission adopted Euratom's 2021-2022 work programme. A total of EUR 99.9 million spread across 16 topics is dedicated to fission research activities under the heading HORIZON-EURATOM-2021-NRT-01.

At the end of 2021, the Commission issued a first Euratom fission call for proposals. After evaluation, 28 proposals were selected for funding, with a Euratom contribution of EUR 117 million ([55]). The funding contracts will be signed during 2022.

The new European partnership for research in radiation protection (topic Horizon-Euratom-2021-NRT-01-09) will be launched in 2022. It will aim to improve the use of ionising radiation in medical applications and radiation detection, which will make a substantial contribution to Europe's Beating Cancer Plan. The partnership will build on the research identified in the roadmap prepared by the 2015-2020 European joint programme for the integration of radiation protection research (Concert).

The programme will also contribute to the implementation of the European research roadmap for the realisation of fusion energy, which represents a long-term option for largescale, lowcarbon electricity production. It could help address a growing low-carbon energy demand towards the end of this century. Before the deployment of fusion power plants, fusion research will enable Europe to create high-tech innovations and, with them, a more competitive high-tech industry.

During 2021-2025, the European partnership in fusion research will build on the progress made by the EUROfusion consortium (2014-2020). It will focus on the further support required for the efficient launch of ITER's operations and, working hand in hand with industry, on increasing the efforts on the conceptual design of a fusion power plant.

54 Council Regulation (Euratom) 2021/765 of 10 May 2021 establishing the Research and Training Programme of the European Atomic Energy Community for the period 2021-2025 complementing Horizon Europe – the Framework Programme for Research and Innovation and repealing Regulation (Euratom) 2018/1563. The programme is limited by the Treaty to 5 years. For this reason, it will cover the years 2021-2025, to be extended in 2025 by 2 more years to align with the 2021-2027 multiannual financial framework.

55 In response to this call, 49 eligible proposals were submitted, requesting a total Euratom financial contribution of EUR 184 million.

## 3.1.5. Activities of the Commission's Joint Research Centre (JRC)

The Euratom research and training programme 2021-2025 includes EUR 532 million for activities to be undertaken by the JRC.

To implement the Euratom programme, the JRC developed its first two-year work programme 2021-2022, which was adopted on 4 June 2021. It is structured according to five project portfolios, which are aligned with the Commission's priorities:

- nuclear energy for energy transition
- promoting reversibility: from nuclear back to the green field
- broadening nuclear knowledge and competence
- strengthening global partnership in nuclear expertise
- nuclear research and innovation for protecting citizens.

In addition, the Euratom and non-Euratom research programmes aim for synergies in the joint project portfolio 'CBRN (chemical, biological, radiological and nuclear) threats and risk mitigation'.

The JRC work programme helps ensure safety in the long-term operation of nuclear reactors, and the development of advanced and innovative reactor safety designs. It includes studies on SMRs, innovative future systems and accident-tolerant fuel. It also contributes to understanding of the behaviour of spent fuel and issues related to nuclear waste management and decommissioning.

To maintain a high level of competence in the field, the JRC carries out education and training activities and opens its installations to EU users to disseminate knowledge and facilitate researchers' mobility.

In 2021, the JRC continued to assess the supply of medical radioisotopes in the EU and perform research on new radioisotope applications and alternative methods of production. These activities support EU initiatives such as SAMIRA and Europe's Beating Cancer Plan. Research on alternative methods of production of radioisotopes of medical interest is included in the JRC's work programme.

The JRC develops tools and techniques in support of the Euratom and international safeguards systems and provides analytical support and reference materials. The European nuclear security training centre provides training for nuclear inspectors on nuclear safeguards, and on nuclear security for front-line officials. These nuclear security activities increase detection capabilities, contributing to global capacity building.

In 2021, JRC scientists contributed to 123 scientific articles published in peer-reviewed journals. The number of technical outputs delivered to users was (i) 11 sets of reference materials and two validated methods that contributed to the modification of international standards; (ii) 16 technical systems for nuclear safeguards; and (iii) six scientific datasets and databases.

**JRC sites in 5 EU Member States**


©JRC

> JRC scientists contributed to numerous scientific articles, modification of international standards, scientific datasets and databases and delivered reference materials. By direct actions addressed specific EU priorities producing technical reports, science-for-policy reports and parts of policy documents.

The outputs produced by direct actions to address specific EU priorities included technical reports, science-for-policy reports and parts of policy documents. These outputs delivered 35 impacts with tangible evidence, in different steps of the policy cycle.

Despite the pandemic restrictions, the use of virtual tools meant that 14 training courses for professionals and students from Member States and the Commission took place. Training provided during this period was aimed at implementing the Basic Safety Standards Directive, and also in support of the

IAEA or to improve Member States' capabilities in nuclear safeguards and nuclear security.

The JRC provided support for the implementation of EU directives (Nuclear Safety and Basic Safety Standards), for instruments such as the Instrument for Nuclear Safety Cooperation and the Instrument contributing to Stability and Peace, and for trade policies such as the dual use of exports. It helped implement the EC safeguards regime both inside the EU and, under the EU's programme in support of the IAEA, outside the EU as well.

Under the EU Sustainable Finance Taxonomy Regulation (see section 3.1.1), the JRC was entrusted with assessing nuclear energy according to the 'do no significant harm' criterion.

### 3.1.6. New framework of cooperation with the United Kingdom in the nuclear field

Following the withdrawal of the United Kingdom from the EU and Euratom, the parties concluded the agreement between the Government of the United Kingdom of Great Britain and Northern Ireland and the European Atomic Energy Community for Cooperation on the Safe and Peaceful Uses of Nuclear Energy [56], which was provisionally applicable from 1 January 2021 and fully entered into force on 1 May 2021.

> Administrative arrangements to implement effectively the agreement between the Government of the United Kingdom of Great Britain and Northern Ireland and the European Atomic Energy Community for Cooperation on the Safe and Peaceful Uses of Nuclear Energy were established.

Pursuant to Article 15 of the Agreement, administrative arrangements had to be established by the parties through their respective competent authorities to implement the agreement. As laid down under Article 2(a) of the agreement, the competent authorities were the Commission, on the side of Euratom, and the Department for Business, Energy and Industrial Strategy and the Office for Nuclear Regulation, on the side of the United Kingdom. The administrative arrangements were signed on 8 January 2022 and became effective on this date. The arrangements cover among other things:

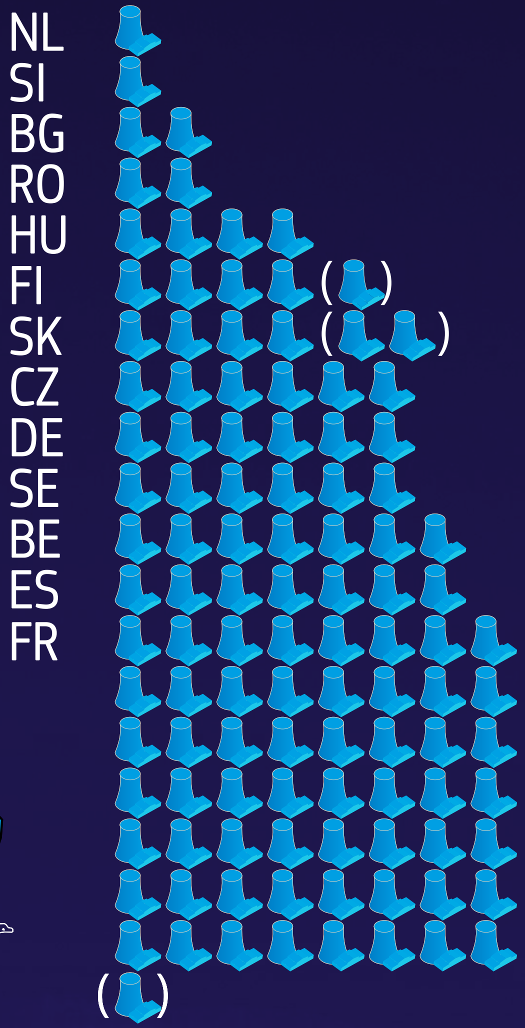
- the accounting and verification of items subject to the agreement;
- channels of communication;
- communication on transfers and retransfers of items subject to the agreement;
- cooperation and exchange of information on the supply of medical radioisotopes and on nuclear safety, radiation protection, radioactive waste management and emergency preparedness and response;
- contact points;
- the protection of data;
- the prevention of unauthorised disclosure of information.

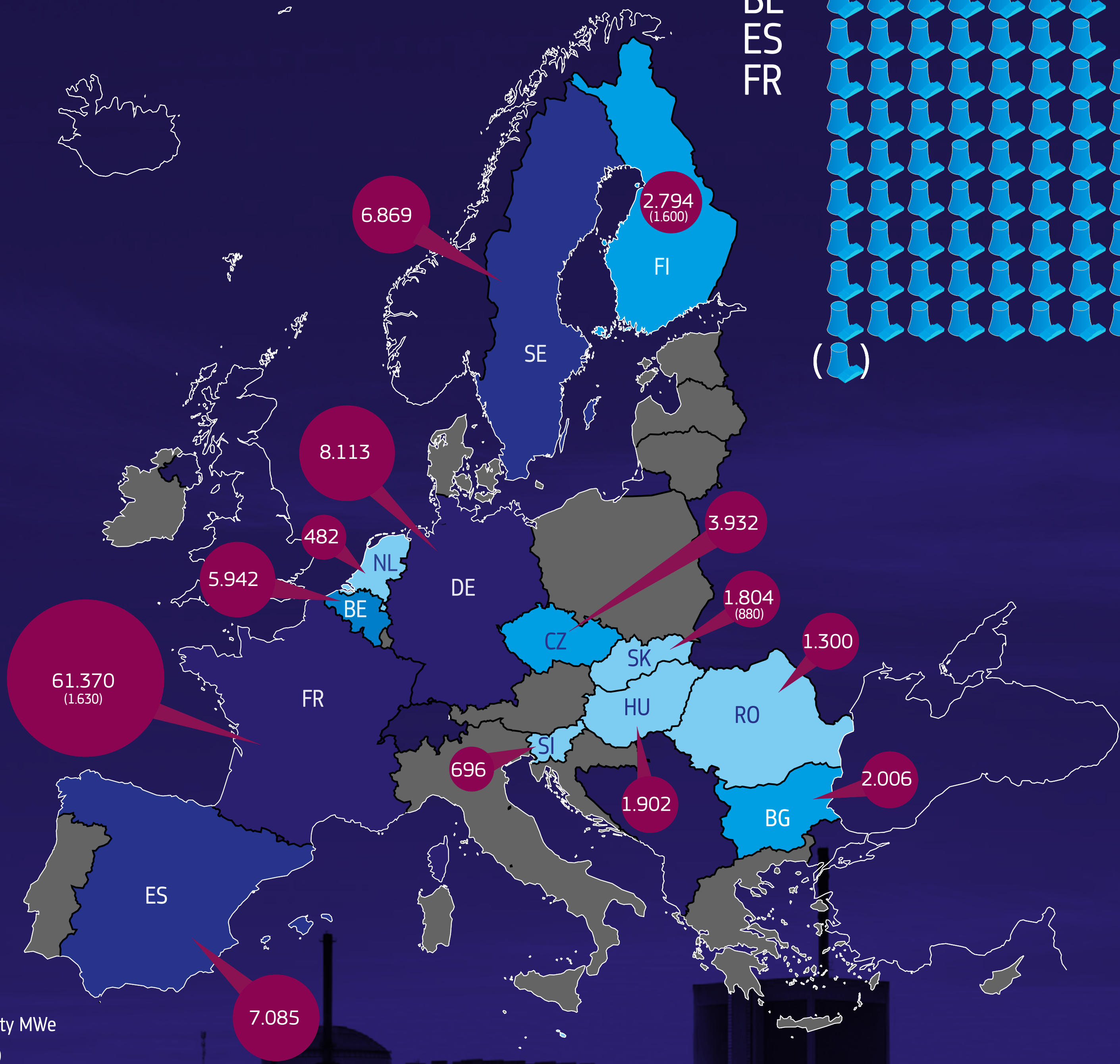
## 3.2. Country-specific developments

At the end of 2021, 106 commercial nuclear power reactors were operating in 13 EU Member States. There were four reactors under construction in France, Slovakia and Finland. In 2021, three reactors were shut down in the EU (Brokdorf, Grohnde and Gundremmingen-C in Germany) (see Table 7).

56 OJ L 150, 30.4.2021, p. 1. Corrigendum OJ L 178, 20.5.2021.

# Nuclear Power in the EU in 2021




Net Capacity MWe

- 0
- 1 – < 2000
- 2001 – < 4000
- 4001 – < 6000
- 6001 – < 8000
- ≥ 8001

**Total**

106 reactors
104.295 MWe
in operation

4 reactors
4.110 MWe
under construction



Cartography: Eurostat – IMAGE, 03/2022

**Table 7. Nuclear power reactors in the EU-27 in 2021**

| Country | Reactors in operation (under construction) | Net capacity (MWe) (under construction) |
|---|---|---|
| **Belgium** | 7 | 5 942 |
| **Bulgaria** | 2 | 2 006 |
| **Czechia** | 6 | 3 932 |
| **Germany (*)** | 6 | 8 113 |
| **Spain** | 7 | 7 117 |
| **France** | 56 (1) | 61 370 (1 630) |
| **Hungary** | 4 | 1 902 |
| **Netherlands** | 1 | 482 |
| **Romania** | 2 | 1 300 |
| **Slovenia (**)** | 1 | 696 |
| **Slovakia** | 4 (2) | 1 804 (880) |
| **Finland** | 4 (1) | 2 794 (1 600) |
| **Sweden** | 6 | 6 869 |
| **Total EU-27** | **106 (4)** | **104 235 (4 110)** |

*(*) Permanent shutdown of Brokdorf, Grohnde and Gundremmingen-C on 31 December 2021.*
*(**) The Croatian power company HEP owns a 50% stake in the Krško NPP in Slovenia.*
*Source: WNA and EU Member States.*

The major developments, decisions and announcements in the nuclear field in the EU Member States are presented below.

## BELGIUM

Tihange 2 was restarted after the Federal Agency for Nuclear Control of Belgium (FANC/AFCN) concluded that no new hydrogen flakes appeared in the walls of the reactor pressure vessel and that the flakes discovered in 2012 had not increased in size. Currently, unit 2 of Tihange NPP is planned for shutdown in 2023, preceded by Doel 3 in 2022, in line with the decision of the Belgian government. The other Belgian nuclear units were planned to be shut down in 2025. However, the government asked FANC/AFCN to examine the possibility of extending the operation of two reactors – Doel 4 and Tihange 3 – if a 2022 report by grid operator Elia indicates that the security of energy supply after 2025 would be jeopardised without nuclear energy ([57]).Elia also published a report, 'Roadmap to net zero', calling for investments in new power interconnectors with the UK and the Netherlands to ensure sufficient electricity after the shutdown of Belgian NPPs, and claiming that their replacement – renewables and natural gas – would not suffice to supply electricity to Belgium.

## BULGARIA

In January 2021, Bulgaria became the 34th member of the OECD's NEA and its Data Bank.

The Bulgarian government tasked the minister for energy with reviewing the prospects of the new nuclear project at Kozloduy NPP Site 2, including the financial and legal aspects and use of the equipment delivered for the Belene project.

Bulgarian companies engaged in talks with US companies dealing with innovative nuclear technologies, including SMRs, to explore opportunities for cooperation. Bulgarian Energy Holding EAD and the US company Fluor, owner of NuScale Power, signed a memorandum of understanding in 2021 on exchanging information and providing preliminary dedicated assistance.

## CROATIA

Croatia expressed interest in co-funding the construction of Unit 2 at the Krško NPP, should Slovenia decide to build it.

57 In March 2022 the Belgian government decided to allow Doel 4 and Tihange 3 to operate until 2035.

## CZECHIA

The Czech government intends to decide on extending the operation of the Temelín NPP. The 'Assessment of the fulfilment of the state energy policy of the Czech Republic' states that a technical and economic study considers the long-term operation of Temelín NPP for 60 and subsequently 80 years.

The government is also committed to carrying out research and development on SMRs and to building new Dukovany unit(s), the first of which is planned to start operating in 2036. The IEA review of Czech energy policies called to identify the role of SMRs with emphasis on the industrial and district heating sectors.

Czechia adopted the new low-carbon energy law,'Lex Dukovany', which sets out a framework for the government to offer guaranteed prices for electricity produced from new reactors for at least 30 years, thus financing the project. The law excludes Russian and Chinese companies from participating in the construction of new reactors. The three potential bidders for the construction of a new nuclear unit at the Dukovany NPP are EDF, Westinghouse and Korea Hydro & Nuclear Power. The evaluation of the bids should be completed by the end of 2024, with the issuance of a building permit expected in 2029. Meanwhile, the Czech State Office for Nuclear Safety issued a nuclear site licence for two new units, each with a capacity of up to 1,200 MW.

## ESTONIA

The Ministry of the Environment set up a nuclear energy working group to analyse the feasibility of using nuclear power in Estonia. The government's decision on nuclear energy is planned to be taken in late 2024.

Estonia agreed with the US to cooperate under the 'Foundational Infrastructure for Responsible Use of SMR Technology' capacity-building programme to increase Estonia's competence in the nuclear sector in general. The Estonian company Fermi Energia signed an agreement with the US GE Hitachi to support the potential deployment of a BWRX-300 small modular reactor in Estonia and, with UK's Rolls-Royce, to study all aspects of potential SMR deployment in Estonia.

Estonia entered the siting phase for its radioactive waste repository. Selection of the site will be finished by 2025 and the repository is planned to be ready by 2040.

## FINLAND

Finland launched legislative preparations for a comprehensive reform of the Nuclear Energy Act. This aims to ensure that the production of nuclear energy will continue to be in the general interest of society, safe and economically viable.

Business Finland, a government organisation that funds innovation, is financing a new SMR development project, Finnish Ecosystem for Small Modular Reactors. Led by VTT Technical Centre of Finland, the project brings together several Finnish organisations to support the development of SMRs. VTT has already begun the first phase of the project to develop SMRs for district heating.

The Radiation and Nuclear Safety Authority in Finland (STUK) granted permission to Teollisuuden Voima Oyj to make the new pressurised water reactor Olkiluoto 3 critical and conduct low power tests. Electricity production would begin in 2022 ([58]).

Fennovoima started construction of the first permanent structure – the first foundation slab of the caissons of the culvert at the standby seawater channel – at the Hanhikivi 1 site. The Finnish Ministry of Defence considers the project sensitive from a geopolitical, economic and fuel supply point of view due to Rosatom's 34% share and has demanded a risk assessment.

Radioactive waste management company Posiva Oy started excavating the final disposal tunnels at the Onkalo underground characterisation facility near Olkiluoto.

Partially used irradiated fuel from the shutdown Finnish Reactor 1 (FiR 1) in Espoo was transported to the United States and the decommissioning permit for the research reactor was issued. The reactor will be dismantled in 2022–2023.

## FRANCE

President Macron announced in November that to ensure French energy independence, France would build new nuclear reactors in addition to the continued massive development of renewable energy sources, while reaching carbon neutrality by 2050. In May, EDF supplied the French government with a proposal for the completion of a programme to construct three pairs of EPR 2s.

The French Nuclear Safety Authority (ASN) approved the operation of the 32 EDF 900 MWe reactors beyond 40 years (for a further 10 years) provided the relevant nuclear safety upgrades are made.

France is supporting the development of SMRs and other innovative reactors expected to reduce nuclear waste, and

58 Olkiluoto 3 was connected to the grid in March 2022.

announced funding of EUR 1 billion (around EUR 500 million for EDF's Nuward project and EUR 500 million for other start-ups) for the industrial deployment of Nuward by 2040.

EDF shut down reactors at Civaux 1 and 2 after defective welds were discovered. Two reactors at Chooz B were also shut down for the inspection of similar welds. Corrosion defects were discovered during ultrasonic testing as part of the units' periodic safety review carried out every 10 years.

Orano's production at the Philippe Coste conversion plant is progressively increasing and is expected to reach 15 000 t by 2023. Orano also is also working on the production of up to 6% enriched uranium by the end of 2023, with higher assay to follow.

A set of contracts was signed by Orano and a number of German utilities to provide for the return by 2024 of all German nuclear waste still stored in France.

The dismantling of Orano's UP2 400 reprocessing plant at La Hague continued with the retrieval of 600 tonnes of legacy graphite and magnesium waste stored in concrete silos and with dismantling at the main plant.

EDF began construction of a demonstration facility for graphite reactor decommissioning, which is expected to begin operation in 2022.

## GERMANY

Germany agreed compensation of EUR 2.4 billion for its four nuclear utilities for losses arising from the country's 2022 nuclear phase-out. The Gundremmingen-C, Brokdorf and Grohnde NPPs were permanently shut down in 2021, in line with the planned nuclear phase-out.

Orano signed contracts worth EUR 1 billion with Germany's EnBW, PreussenElektra, RWE and Vattenfall to return the radioactive waste from reprocessing during 1977-1991 and which remains at Orano's La Hague reprocessing plant. The waste is to be returned to Germany by 2024.

RWE contracted Westinghouse to dismantle two reactors at the Gundremmingen NPP and a consortium of Framatome and Transnubel to dismantle the Emsland NPP.

## HUNGARY

Following an application for a construction licence for the two new VVER1200 units submitted by the NPP Paks II in July 2020, the Hungarian Atomic Energy Authority (HAEA) conducted nuclear technology safety assessments. In addition to the thorough documentation submitted, HAEA asked for further clarifications to be able to fully verify all the requirements. Additional assessment and analysis are needed, following the recommendations of the IAEA's visit that took place in parallel with the licensing process. The Paks 2 NPP is expected to start construction in 2022 and begin operation in 2028-2029.

Hungary signed a nuclear cooperation agreement with South Korea in November 2021.

The programme of the Budapest University of Technology and Economics (BME) was endorsed by the IAEA in 2020 as part of the International Nuclear Management Academy (the seventh such university worldwide). In December 2021, BME was the first university in the world to host a Level 3 IAEA Knowledge Management Assist Visit, offered by the IAEA to countries with the most advanced nuclear programmes. The academic programmes received positive evaluations.

## ITALY

In 2021, Ansaldo Nucleare and its partner Monsud signed a five-year, EUR 105 million contract with Fusion for Energy, to design, implement, test and commission the emergency electrical power distribution system for ITER.

Sogin, Italy's state-owned company responsible for decommissioning, started preliminary activities to decommission the ISPRA-1 research reactor on the site of the JRC of the Commission.

## LITHUANIA

The Ignalina NPP finished defueling and reported progress in line with the plan to fully decommission the plant by 2038.

Lithuania started the process for siting a geologic spent fuel repository, planning to have the facility operational in 2068.

## NETHERLANDS

The Dutch government decided to strongly support nuclear energy, placing it at the centre of its climate and energy policy. It allocated approximately EUR 500 million until 2025 to support new nuclear build, with more funding planned to follow gradually until 2030. The lifetime of the Borssele NPP is therefore also planned to be extended beyond 2033 as originally scheduled.

The Reactor Institute Delft and the IAEA expanded their collaboration in neutron activation analysis to neutron beam-based methodologies, a key technique in materials research, biology and medicine.

## POLAND

Poland adopted its energy policy until 2040 (PEP2040). It provides for a significant reduction in the power generated by coal by 2030 and the introduction of renewables and nuclear energy into its energy mix.

In 2021, Poland decided to build NPPs with a total of 6.0–9.0 GW(e) of installed capacity using large PWR reactor technology. The construction of the first NPP is planned to start in 2026 and become operational in 2033. In reaction to the statement by the Polish government that it is looking for investors for a 49% share in its new nuclear projects, EDF was the first to submit an offer for the construction of four to six EPR nuclear reactors with an installed capacity of up to 9.9 GW. Offers from Westinghouse and Korea Hydro & Nuclear Power are expected to follow.

Polish oil and gas producer PKN ORLEN signed a nuclear cooperation agreement and launched a joint venture with Polish chemicals and industrials firm Synthos to pursue the development and operation of micro and small modular reactors. Synthos also signed an agreement with ZE PAK to explore the possibility of building an SMR at ZE PAK`s Pątnów coal plant. Moreover, Synthos signed a memorandum of understanding with Cameco, GE Hitachi Nuclear Energy and GEH SMR Technologies Canada Ltd to evaluate a potential Canadian supply chain for a fleet of BWRX-300 reactors in Poland.

The Polish companies KGHM Polska Miedź SA and Piela Business Engineering came to an agreement with NuScale Power to explore the deployment of NuScale's SMR technology at existing coal-fired power plants in Poland.

Westinghouse Electric Company established a global shared service centre in Poland in 2021 and launched front-end engineering and design work to advance the nuclear energy programme in Poland.

### ROMANIA

The Romanian government's 2021-2030 national integrated energy and climate plan envisages two new CANDU reactors at Cernavodă by 2031 and the modernisation of an existing unit by 2037. Following the 2020 intergovernmental agreement on cooperation to expand and modernise Romania's nuclear power programme signed between Romania and the United States, the first contract was signed with the Canadian Candu Energy company in November 2021 for the preparation of the licensing of the two new CANDU reactors at Cernavodă.

Nuclearelectrica bought from Compania Națională a Uraniului assets within the uranium concentrate processing line at Feldioara and set up a uranium concentrate processing branch, Uranium Concentrate Processing Factory-Feldioara, to process nuclear fuels.

After the closure of the only operating uranium mine (Crucea) in Romania, the Romanian Minister for Energy announced the opening of another uranium mine (Tulgheș-Grințieș) to ensure that Romania maintains its own source of nuclear fuel.

In January 2021, Romania was awarded a grant by the US Trade and Development Agency to finance the costs of technical assistance to identify and assess potential sites suitable for SMR technologies in Romania and to develop a roadmap for their licensing. Later in the year Nuclearelectrica signed an agreement with NuScale to advance the deployment of NuScale's SMR technology, i.e. a 6-module (462 MWe) power plant, in Romania before 2030.

### SLOVAKIA

Slovenské Elektrárne received a permit to start commissioning unit 3 of the Mochovce NPP. Fuel loading is expected in 2022. Slovenské Elektrárne also performed efficiency upgrades and uprated Mochovce 1 & 2 to a total of 1 000 MWe.

The Slovak parliament decided to ban the processing of foreign radioactive waste or spent fuel in Slovakia. These services are provided by JAVYS, a company in charge of RAW management and decommissioning.

Slovakia decided to suspend payments into the nuclear decommissioning fund for 2 years. This decision should help alleviate high electricity prices. Payments to the fund should resume in 2024.

### SLOVENIA

The Slovenian government granted the energy permit for the proposed Krško 2 unit in 2021. This is the first step in the process to possibly build a new NPP unit at the Krško site, for which a proposal to start the spatial planning procedures was submitted to the Ministry for the Environment and Spatial Planning.

### SPAIN

The operating licence of the Cofrentes NPP was renewed, allowing it to continue operating until 2030. The Ascó NPP units I and II were also granted operating licence extensions to 2030 and 2031 respectively. An operating licence for the Trillo I NPP was amended, extending the operation for 3 more years.

The Spanish parliament approved an amendment to the draft climate change and energy transition bill that put an end to the possibility of new applications for the exploration, investigation or exploitation of radioactive materials mines, as well as of new applications for radioactive installations of the nuclear fuel cycle.

The Spanish Nuclear Safety Council issued a binding negative report on Berkeley Energia's Retortillo uranium concentrate plant project in Salamanca. This was due to a lack of reliability and a high level of uncertainty about the geotechnical and hydrogeological aspects, on which the verification of the adequate behaviour of various project parameters depend.

Enusa Industrias Avanzadas and the IAEA signed a cooperation agreement to work on environmental protection and rehabilitation after the decommissioning of nuclear facilities, on waste management, and the transportation of nuclear and radioactive materials.

### SWEDEN

Uniper Sweden created a joint venture with LeadCold and the Royal Institute of Technology to potentially construct a demonstration LeadCold Sealer lead-cooled SMR at Oskarshamn by 2030. The reactor is planned to generate 3-10 MWe over a 10-30 year period without the need for refuelling.

The Swedish government approved Svensk Kärnbränslehantering Aktiebolag (SKB)'s application to extend the final repository for short-lived radioactive waste (SFR) in Forsmark. The facility needs to be extended to accommodate waste from the decommissioning of Swedish nuclear power plants. On 27 January 2022, the Swedish Government decided to allow SKB to build a final repository for spent nuclear fuel in Forsmark in Östhammar Municipality and an encapsulation plant in Oskarshamn.

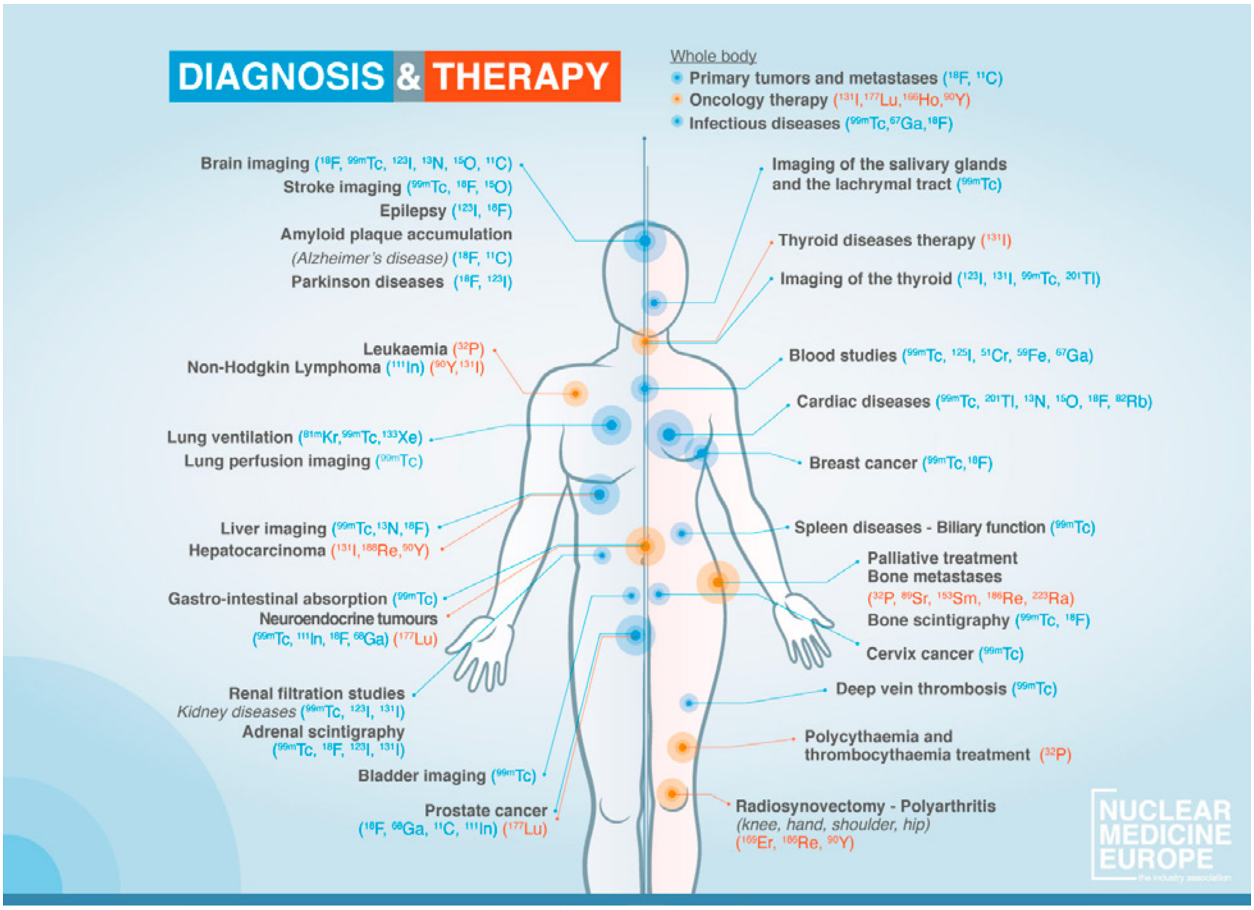
## 3.3. Non-power applications of nuclear technology: the supply of medical radioisotopes

Radioisotopes are used in medicine to diagnose and treat various diseases, including life-threatening ones like cancer or cardiovascular and brain diseases. Over 10 000 hospitals worldwide use radioisotopes in about 100 different nuclear medicine procedures, with almost 49 million medical procedures each year. In the EU alone, more than 1 500 nuclear medicine centres deliver around 10 million procedures to patients each year. Nuclear medicine is an important tool for cancer management: depending on national practice, around 60% of all nuclear medicine procedures are performed in oncology. The therapeutic use of medical radioisotopes in cancer treatment is expanding, with the market for novel radiopharmaceuticals expected to grow massively over the next few years.

Currently, the main source of radioisotopes is nuclear research reactors, with several other non-fission technologies such as cyclotrons and accelerators in use or under development. Radioisotope production technologies mostly rely on highly specialised supply chains that usually stretch across countries and continents and involve 24/7 just-in-time delivery.

Technetium-99m (Tc-99m) is the most widely used radioisotope. It is used in 80% of all nuclear medicine diagnostic procedures. The production of Tc-99m starts with irradiation of uranium targets in nuclear research reactors to produce Molybdenum-99 (Mo-99), then extraction of Mo-99 from targets in specialised processing facilities, production of Tc-99m generators and shipment to hospitals. Any disruption to supply may have negative and sometimes severe consequences for patients.

**Uses of medical radioisotopes (Hygieia poster)**



The EU plays a central role in the nuclear medicine domain. It has a unique complete supply chain network:

- a uranium fuel and target manufacturer: Framatome-CERCA in France;
- four research reactors irradiating uranium targets: BR2 in Belgium, HFR in the Netherlands, MARIA in Poland, and LVR-15 in Czechia;
- two uranium targets processing facilities: Curium in the Netherlands and IRE in Belgium;
- major Tc-99m generators manufacturing sites in the Netherlands, France, and Poland.

The EU is a leading supplier of medical radioisotopes to the world market, with a share of more than 60% for Mo-99/Tc-99m. Some of the most important pharmaceutical and clinical developments in nuclear medicine also originated in the EU.

## 3.3.1. Reactor scheduling and monitoring the supply

The Security of Supply Working Group ([59]) of the industry association of nuclear medicine (NMEu) ensures the effective coordination of reactor maintenance schedules to avoid and mitigate disruptions in the supply of Mo-99/Tc-99m. The Emergency Response Team (ERT), created within this working group and composed of representatives of research reactors, Mo-99 processors and Mo-99/Tc-99m generator manufacturers, monitors production and supply issues. This continuous monitoring makes it possible to identify potential shortages of Mo-99 and draw up mitigation action plans involving all stakeholders.

In 2021, the group focused on dealing with the unplanned outage of the Australian OPAL research reactor in March-April and the unplanned production stop at the Belgian IRE Mo-99 production line in December. NMEu's ERT support was instrumental in dealing with those supply disruption issues. The joint communication team (JCT), created with the Observatory, provided regular information updates received from the ERT to various stakeholder groups, including the EU administrations, OECD/NEA and IAEA.

In October, the group provided information about a potential shortage of Iodine-131 (I-131) for nuclear medicine therapy in the second half of 2022, indicating the need for the approved marketing authorisation of I-131 from HALEU targets before the end of production of I-131 from HEU targets. Informed by ESA, the EMA and the Co-ordination Group for Mutual Recognition and Decentralised Procedures – Human (CMDh) ([60]) agreed a work-sharing procedure to avoid that multiple evaluations would be carried out by individual competent authorities and to facilitate a coordinated approach.

## 3.3.2. SAMIRA

On 5 February 2021, the Commission presented its SAMIRA action plan[61], which is the first follow-up to Europe's Beating Cancer Plan, adopted by the Commission on 3 February 2021. It will improve EU coordination to ensure that radiological and nuclear technologies continue to provide health benefits for people in the EU and contribute to the fight against cancer and other diseases.

> The SAMIRA action plan, which is the first follow-up to Europe's Beating Cancer Plan adopted by the Commission will improve EU coordination to ensure that radiological and nuclear technologies continue to provide health benefits for people in the EU and contribute to the fight against cancer and other diseases.

The action plan was developed under the leadership of the Directorate-General for Energy in collaboration with the Directorate-General for Health and Food Safety, the Directorate-General for Research and Innovation, the Directorate-General for Education and Culture, the JRC, and the ESA. It sets out actions and measures in three key areas: (i) securing the supply of medical radioisotopes, (ii) improving radiation quality and safety in medicine, and (iii) facilitating innovation and the technological development of medical applications of ionising radiation.

59 http://nuclearmedicineeurope.eu/security-of-supply.
60 Heads of Medicines Agencies: CMDh (hma.eu).
61 https://ec.europa.eu/energy/sites/default/files/swd_strategic_agenda_for_medical_ionising_radiation_applications_samira.pdf.

European Commission

05 February 2021

**SAMIRA** (Strategic Agenda for Medical Ionising Radiation Applications)

Commission Action Plan to support Europe's fight against cancer

**Radiological and nuclear technologies play a crucial role in modern healthcare.** They are indispensable in the fight against cancer and contribute to all stages of cancer patients' care, including early detection, diagnosis, treatment and palliative care. They are also widely used in other medical fields, from regular x-rays to diagnosing cardiac conditions and other diseases.

The **SAMIRA Action Plan** ensures that **EU citizens have access to high-quality radiological and nuclear technologies in medicine** with the highest safety standards. It is an important part of the **Europe's Beating Cancer Plan**.

Under the action plan, the Commission is to:

- establish a European Radioisotope Valley Initiative to maintain Europe's global leadership in the supply of medical radioisotopes and help accelerate the development and introduction of new radioisotopes and production methods;
- launch a European initiative on the quality and safety of medical applications of ionising radiation, to ensure that diagnostic and therapeutic uses of ionising radiation in Member States operate in line with the highest standards;
- create synergies between the Euratom research and training programme and the 'Health' cluster of the EU Horizon Europe research and innovation programme, through the development and implementation of a research roadmap for medical applications of nuclear and radiation technology.

Several activities to carry out the SAMIRA action plan took place in 2021 under the different work strands. Among them, the Commission concluded a study contract ([62]) on radioisotope supply chains and scenarios for the supply of radioisotopes in the EU by 2040. The study will provide key evidence and analyses for stakeholder discussions on ERVI, which will kick off in 2022.

**Equipment in oncology department. Nuclear Medicine**

*© Alex Tihonov, stock.adobe*

## 3.3.3. Studies and research

### The supply chain's back end

The JRC ended the SMER 2 study with a stakeholder workshop in January 2021, followed by publication of the report ([63]), which provided the Commission with up-to-date information

62 https://op.europa.eu/en/publication-detail/-/publication/4599de47-3ac6-11ec-89db-01aa75ed71a1/language-en.
63 https://publications.jrc.ec.europa.eu/repository/handle/JRC124565.

on the radionuclide therapy market in the EU, including a forecast of demand. The project's research on new medical uses of promising radionuclides, alternative methods of production and collaborations to tackle the challenges to clinical use are ongoing at the JRC. All these activities support other EU initiatives, including the European Observatory on the Supply of Medical Radioisotopes, the Cancer mission of Horizon Europe, the SAMIRA initiative and Europe's Beating Cancer Plan.

### Conversion of targets for Mo-99 production to HALEU

Alongside the successful 2015–2020 Heracles-CP [64] project, a complementary project, FOREvER [65], kicked off in 2017 to optimise the manufacturing process of new types of reactor fuels. The project, which runs until 2022, is coordinated by the French Alternative Energies and Atomic Energy Commission (CEA) and involves nine research partners. Its aim is to foster the development of sustainable and innovative low-enriched uranium fuel elements for the whole spectrum of European research reactors.

In 2021, the LVR-15 reactor in Czechia obtained a permit to introduce new fuel created within the FOREvER project. The fabricated fuel assembly was subsequently transported from the production plant to the reactor facility and is ready for use in a suitable reactor operation campaign; it will be the first use of Si-U-based fuel in this facility.

Building on the data of Heracles-CP and FOREvER, the EU-Qualify [66] project started in October 2020 and will last until 2024. Coordinated by the Belgian Nuclear Research Centre (SCK-CEN) and involving five partners, the project will generate data needed for the generic fuel qualification of two main fuel types (U-Mo and 'high-loaded' uranium silicide $U_3Si_2$). The project's main objective is to support the investigation of future needs for each EU research reactor type in terms of volume and fuel design requirements, in line with relevant data. It will also prepare technical requirements for the safety of manufacturing, storage, transport and reprocessing of this research reactor fuel.

### Prismap

The key objective of the Prismap [67] project is to establish European infrastructure and a common entry point for researchers and physicians, thus speeding up the introduction of new medical radioisotopes. In September, the Prismap [68] network was launched, which groups together 23 European academic institutions and research centres. They will pool their knowledge, expertise and infrastructure to provide a sustainable source of high-purity grade novel radionuclides for medical research.

## 3.3.4. Projects on the non-power applications of nuclear technology

In 2021, major projects on the non-power applications of nuclear technology were started or continued, with several milestones reached.

### Petten HFR – Pallas

The Petten HFR reactor achieved a record level of production in 2021, supplying over 30 000 patients with medical radioisotopes every day. The Nuclear Research and Consultancy Group (NRG) saw increased demand for supplies from European producers of radioisotopes due to transport and logistic issues related to the COVID-19 pandemic. NRG is developing several new radiochemicals as part of its Field-Lab [69] initiative. Work on the Pallas [70] reactor in the Netherlands continued, with the basic design completed. A construction permit for the Nuclear Health Centre – a general processing facility for therapeutic isotopes – has been granted.

### Jules Horowitz Reactor

In October, the Jules Horowitz Reactor (JHR) project [71] went a whole year without a loss-time accident. The approval of the JHR roadmap by the French authorities cleared the project path and validated the strategy, based on completing design studies before accelerating work on the electromechanical installation. The safety report at the end of 2021 initiated the licensing process. In 2021, several major milestones in the reactor's construction were reached. Extensive work was carried out in the TOTEM facility for the underwater and hot cell non-destructive examination bench tests. The detailed design of the Lorelei [72] loop was completed and delivered to the French Alternative Energies and Atomic Energy Commission (CEA) with all the associated documents.

### SCK-CEN

SCK-CEN is successfully advancing towards the conversion of the BR-2 reactor from HEU to LEU fuels. Irradiations of candidate high-density LEU fuel elements have been

64 'Towards the conversion of high-performance research reactors in Europe', EUR 6.35 million, https://cordis.europa.eu/project/id/661935/fr.
65 'Enriched Uranium Fuels fOR REsEarch Reactors', EUR 6.6 million, https://cordis.europa.eu/project/rcn/210823_en.html.
66 'European qualification approach for low-enrIched fuel systems for secure production supply of medical isotopes', EUR 7.80 million, https://cordis.europa.eu/project/id/945009/fr.
67 The European medical isotope programme: production of high purity isotopes by mass separation, EUR 5.0 million, https://cordis.europa.eu/project/id/101008571.
68 https://www.prismap.eu/.
69 https://www.advancingnuclearmedicine.com/en/field-lab.
70 https://www.pallasreactor.com/en/.
71 http://www-rjh.cea.fr/index.html.
72 Light water One Rod Equipment for LOCA Experimental Investigations.

completed and their post-irradiation examinations are expected to confirm in 2022 the feasibility of the conversion. The manufacturing of lead test assemblies has already commenced.

## MARIA

Throughout 2021, the MARIA research reactor continued to supply radioisotopes for research, industry, diagnosis and treatment. With four cycles dedicated to Mo-99 production, the National Centre for Nuclear Research (NCBJ) gained useful operational knowledge and has demonstrated its ability to supply vital medical radioisotopes.

The goal is to stay on track while improving competence and preparing for long-term operation. In the first quarter of 2021, the new targets for I-131 production were applied in the MARIA reactor. They allow a fourfold increase in the activity of the irradiated target with significantly reduced heat generation. Irradiations of Lu-177 and Holmium-166 (Ho-166) are also carried out.

## LVR-15

Following the extension of its operating licence in 2020, the LVR-15 reactor in Czechia met the conditions set for 2021 and continued to operate. Its operation included further testing of the irradiation of LEU targets for the production of Mo-99, with the aim of full conversion in line developments in this area.

## Iodine-131

In the National Institute for RadioElements (IRE), the conversion project to LEU moved forward with the full validation of the I-131 purification process. Production will gradually convert to LEU, with full completion expected by the end of 2022.

## Cobalt-60

In December, Westinghouse Electric Company and EDF signed a memorandum of understanding to produce Cobalt-60 (Co-60) in selected pressurised water reactors (PWRs) owned and operated by EDF in France. The agreement is the first step towards production in Europe of this radioisotope for medical uses. Co-60 is used to sterilise medical devices and is also used in cancer treatment. Under the memorandum, Westinghouse would manufacture Cobalt-59 capsule fuel assembly inserts - or COBAs - for EDF to irradiate in its PWRs to generate activated Co-60. The first Co-60 harvest is planned in the early 2030s.

## Actinium-225

IBA (Ion Beam Applications SA), the world leader in particle accelerator technology, and SCK-CEN announced a strategic R&D partnership for the production of Actinium-225 (Ac-225), a novel radioisotope which has significant potential in the treatment of cancer. With support from the EU's recovery plan for Europe, SCK-CEN and IBA will contribute to ensuring a large-scale, stable and sufficient supply of two of the most promising radioisotopes for targeted radiotherapy (Lu-177 and Ac-225).

## Myrrha

The Myrrha project [73] - the world's first prototype of a subcritical lead-bismuth cooled reactor driven by a particle accelerator - reached important development milestones in 2021. For the first time, researchers at the Belgian Nuclear Research Centre (SCK-CEN) succeeded in accelerating a proton beam through the connected radio frequency quadrupole (RFQ), a component of the particle accelerator. In a breakthrough SCK-CEN had been working towards for 6 years, which was the result of international collaboration, the RFQ produced a proton beam according to the exact requirements to drive the particle accelerator. In addition, a cryomodule prototype was developed. The non-profit organisation AISBL Myrrha was officially founded, with the purpose of attracting international partners to the consortium.

## Recumo

The Recumo [74] project, a partnership between SCK-CEN and the National Institute for RadioElements (IRE), aims to purify HEU and LEU residues that originate during Mo-99/Tc-99m production from irradiated HEU and LEU targets at IRE, and to convert these residues into a down-blended and purified LEU suitable for re-use. Secondary radioactive waste streams will be conditioned and removed according to Belgian standards. The detailed design of the Recumo facility was finished in 2021 and the licensing of the facility received positive opinions from the Federal Agency for Nuclear Control, the Belgian nuclear regulator.

## Stable isotopes

In October, Urenco Stable Isotopes expanded its stable and medical isotopes facility in Almelo, the Netherlands, officially opening its new Leonardo da Vinci cascade. The new cascade is designed to enrich multiple radioisotopes, including cadmium, germanium, iridium, molybdenum, selenium, tellurium, titanium, tungsten, xenon and zinc. Each year, more than 100 000 patient treatments are performed using nuclear medicines produced with Urenco's stable radioisotopes.

Also in October, ORANO completed the construction of a new laboratory for the production of stable isotopes at its Tricastin site in France. The laboratory will begin operation in the second half of 2023.

73 Multi-purpose hYbrid Research Reactor for High-tech Applications, https://www.sckcen.be/fr/projets/myrrha.
74 https://www.sckcen.be/fr/projets/recumo.

## Fuel for TRIGA reactors

In April, TRIGA International, a joint venture between General Atomics and Framatome's CERCA, completed a major renovation project at its fuel fabrication facility in Romans-sur-Isère in France, which is the only supplier of uranium-zirconium hydride fuel for 36 TRIGA-type research reactors around the world. The facility resumed operation in December, after receiving the authorisation to restart from the French regulator, ASN.

## Other production methods

The new 30 MeV cyclotron will enable IRE to produce Germanium-68 (Ge-68), the raw material for the Germanium-68/ Gallium-68 generators. The engineering phase for the new building is complete and the manufacture of the cyclotron by the company IBA has been progressing well. The generators are manufactured on the Fleurus site by its pharmaceutical subsidiary IRE ELiT to serve hospitals around the world. Gallium-68 (Ga-68), the end product extracted from these generators, is in growing demand as it can provide an accurate and earlier diagnosis of many cancers through the use of PET (positron emission tomography) camera technology.

The R&D phase of IRE's SMART project (accelerator-based production of Mo-99) made progress. Some testing took place, as well as preparation for a very important proof of concept test called 'Mini Lighthouse', scheduled for February 2022 and intended to validate the mathematical models and simulations.

In May 2021, the US company SHINE Technologies LLC (SHINE) ([75]) announced their decision to build a European production facility in Veendam (the Netherlands) and established SHINE Europe BV. SHINE's technology uses a low-energy, accelerator-based neutron source to fission an LEU target dissolved in an aqueous solution to produce Mo-99. The SHINE system can also produce medical radioisotopes via activation. The Veendam plant is expected to be operational as early as 2026, with Mo-99 as the first radioisotope, which will be followed by others, including Lu-177.

In June, Ion Beam Applications SA (IBA) launched its new high energy and high-capacity cyclotron, the Cyclone® IKON, which offers the broadest energy spectrum for PET and SPECT Isotopes from 13 MeV to 30 MeV. In September, the University of Coimbra's Institute for Nuclear Sciences Applied to Health, in Portugal, and IBA announced the granting of the first EU marketing authorisation for the distribution of cyclotron-produced Gallium-68 using a liquid target for human use.

**JRC Gelina neutron time-of-flight facility in Belgium**

©JRC

75 https://shinemed.com/.

# 4. World market for nuclear fuels in 2021

The year saw six new nuclear power units connected to the grid, nine permanent shutdowns and seven construction starts (of which five in China). This brought the reactor count down to 439, after a rising trend since 2010. Global net installed capacity fell by 1.8% from the previous year. Growth prospects for nuclear power remain mostly centred in Asia, home to most of the reactors under construction.

With input and SWU costs on the rise and secondary supplies depleted or nearly so, uranium prices appear to have reversed the previous downward trend. The year saw growing appetite from private investors to stockpile uranium and invest in projects aiming to develop advanced fission reactors.

An increasing number of countries are looking to build new reactors, and not only to generate electricity. Earlier decisions to retire nuclear capacity are in some cases being reversed and in some countries public opinion seems more receptive to viewing nuclear power as a contributor to decarbonisation, also via hydrogen production.

Transitioning the world from carbon to hydrogen would require massive electrification efforts and could prompt a surge in demand for low-carbon electricity production.

Alongside large electricity-producing nuclear reactors, small and modular ones, both land-based or maritime, are constantly mentioned as options to power remote sites and projects. The recent space plans of major economies would see nuclear power established on the moon.

> Interest in SMRs has been growing in some EU countries.

Development of advanced claddings and fuels, resistant to higher temperatures and to accidents, is progressing rapidly, calling on regulators to update licensing procedures and criteria.

At the COP-26 United Nations Climate Change Conference, the role of nuclear energy in tackling the climate crisis was underlined by some pro-nuclear stakeholders, as was its possible contribution to a net zero world.

As older wind turbines need to be retired (approximately half of European capacity by 2030) with fewer subsidies available, the timelines and costs of dismantling and repowering have raised questions and fuelled debate on the timeliness of nuclear power phaseouts.

Despite COVID-19 concerns, extractive industries in general, and uranium mining in particular, demonstrated resilience. That said, supply chains have been under stress, heating up commodities markets in general. With the prospect of higher uranium prices, various players are considering whether to reopen mines.

In the EU, Member States are free to develop nuclear power and to decide on its contribution to their energy mix, in mutual respect and observance of the goals of the Community. Several Member States continue to see potential for nuclear energy as part of their energy portfolio. Interest in SMRs has been growing in some EU countries. France joined the Nuclear Innovation: Clean Energy Future initiative (NICE Future) an international initiative of the Clean Energy Ministerial, currently led by the UK, the US, Canada and Japan, which aims to address nuclear energy within the context of broader clean energy systems.

Maritime aspects are receiving increasing attention. The International Maritime Organization completed an analysis of ship safety treaties, including the carriage of irradiated nuclear fuel (INF) code, and a study was published on the possible contribution of nuclear-derived, zero-carbon fuels to help decarbonise maritime shipping. Deep sea container shipping could benefit from nuclear propulsion.

The construction of large nuclear power stations continues to take place, particularly in Asia. See below for more information.

**Four Mile ISL mine Australia**

©Luminita Garcia

# 4.1. Country-specific developments

### Argentina

While only 5% of the country's electricity comes from nuclear power, Argentina has a significant nuclear industry and know-how, and plans to increase its nuclear fleet with the help of China (Hualong One for Atucha-III) and Canada (Candu). Nucleoeléctrica Argentina and CNEA signed a contract to complete the Carem-25 SMR reactor building. News also emerged about a possible sale of Invap reactors to China for isotope production.

Besides work on the RMB reactor at Iperó in Brazil, Argentina's Invap reported work underway on the low-power research reactor near Riyadh (Saudi Arabia) as well as on modernising the Nur reactor at Draria (Algeria). Meanwhile, Canadian company Blue Sky Uranium announced plans to expand and upgrade the Ivana Deposit in Rio Negro Province.

### Armenia

Rosatom announced that it had completed the life extension and modernisation programme of the Metzamor NPP unit 2. With around 30% of the country's power hinging on a sole NPP, the government has plans to build another station.

### Australia

Australia is known for its uranium resources, the world's largest. The country exports all its production and ranks fourth among the world's uranium producers.

Exploration is not only domestic, and Australian firms continue to lead various exploration projects in Africa and Canada. While Australia is to remain a key producer, the closure in January of the Ranger uranium mine is forecast to reduce the country's uranium output in the medium term by up to 30%. This could be mitigated by the recently approved Mulga Rock project, due to start in 2025, and a recovery in the output of Olympic Dam in 2022-23. The development of other deposits has already been considered, and could materialise if market prospects are favourable.

Though Australia uses no nuclear power, it operates research reactors and has been active in developing and producing radioisotopes. The country is also active in other fuel cycle technologies: Australian Silex Systems Limited, for example, owns technologies to develop innovative uranium enrichment processes. In March, a second operation to repatriate vitrified radioactive waste was completed.

Australia's federal government selected the Napandee site to house a facility to permanently dispose of the country's low-level radioactive waste and temporarily store intermediate-level radioactive waste. Meanwhile, earlier proposals to set up an international nuclear repository in Australia have not been followed up.

### Belarus

Constructed by Russia's Atomenergomash, the first nuclear unit in Belorussia, Astravyets-1, began commercial operation in June, generating 27.5 million kWh of electricity per day. The IAEA carried out IPPAS and IRSS site visits. Rosenergoatom's improvements in operational safety were noted by an IAEA OSART site visit.

Following a preliminary report, a team of experts (under Ensreg's mandate) completed a peer review of the Belarusian authority's national action plan, using EU stress test specifications as the reference. Released in November, the final report identified some areas where further safety improvements could be made.

Meanwhile, automatic shutdowns at Astravyets-1 were reported in July and November, the longest of which was attributed to an issue with an element of the turbogenerator system. Rosatom announced the carrying out of hot functional testing at Astravyets-2, and in December, government sources announced completion of the loading of the reactor with 163 fuel assemblies. A WANO ([76]) team carried a pre-start-up peer review.

### Brazil

Brazil has two nuclear reactors, generating about 3% of its electricity. At COP26, plans for additional nuclear plants were announced.

Construction of the country's third nuclear power unit gained new momentum after the restructuring of Eletrobras. In July, a contract to resume construction of Angra Unit 3 was awarded to the Angra Eurobras NES consortium. Meanwhile, the Brazilian dry storage spent fuel facility at the Angra NPP officially started operation, planned for 50 years.

Meanwhile, Brazil's Amazul and Argentina's Invap presented details of the planned Brazilian versatile 30 MW reactor, designated RMB, which will operate with uranium enriched to 19.75% and is designed to cover the country's needs for medical radioisotopes.

### Canada

Canada remains a world leader in nuclear research and technology and one of the largest sources of primary uranium supplies. Canada's Athabasca Basin is possibly the world's richest uranium jurisdiction, including the world's highest-grade uranium mine, Cigar Lake. Total packaged production from Cigar Lake alone in 2021 was 12.2 million lb $U_3O_8$, up from 10 million lb $U_3O_8$ in 2020. In May 2021, Cameco announced that production at the Cigar Lake mine had resumed after suspension in late 2020. Cameco revised its outlook for 2021, increasing $U_3O_8$ inventory to 12 million lb after Cigar Lake's resumption of activity. Fuel (conversion) services however were revised down to 11.5-12.5 million kgU. Loan facilities up to 2023 are valued at 2.0 million kgU $UF_6$ conversion and 2.6 million lb $U_3O_8$. A possible restart of the McArthur River mine (formerly the world's richest uranium mine) could propel the country higher up the list of the world's top producing countries.

The year also saw news about other mining projects, influenced by developments in uranium prices. Various projects in the Athabasca Basin have potential for development. Denison announced an estimated 9.7 million lb $U_3O_8$ would be recoverable over a six-year production period for the Waterbury Lake in-situ recovery project (4 310 tU) and the discovery of new high-grade uranium mineralisation at its McClean Lake Joint Venture. Five-year tests of the novel SABRE mining technology were completed in December at the McClean Lake property.

Uranium featured in Canada's critical mineral list of 31 entries, unveiled in March. Canada and the United States reaffirmed their wish to strengthen cooperation on security of supply chains and critical minerals.

As in previous years, the country saw developments spurred by the Canadian Roadmap for SMR. A formal licensing review of Ultra Safe Nuclear Corporation's (USNC) 15 MWe Micro Modular Reactor (MMR) was launched, with first power planned for 2026. Bruce Power and Westinghouse unveiled a feasibility report for the eVinci microreactor. Nuscale teamed up with Prodigy and Kinectrics on the licensing and deployment of a Prodigy marine power station.

Bruce Power, which is operating eight CANDU reactors in Ontario, received regulatory approval for the commercial production of the medical radioisotope lutetium-177 (Lu-177) in its nuclear power plants.

Canada's Candu Energy won a bid for engineering services to future Cernavodă units.

Ontario Power Generation announced a project with Moltex to demonstrate the technical viability of a new process to recycle used CANDU fuel. Meanwhile, Canada's Nuclear Waste Management Organization has completed borehole drilling work at Ignace which, alongside South Bruce, are the two possible host areas being considered for a deep geological repository for Canada's used nuclear fuel.

Cameco progressed in its licence applications to expand the Port Hope CANDU fuel fabrication facility, and to extend the life of its Blind River refinery. The company also upped its participation in SILEX technology licensee Global Laser

76 World Association of Nuclear Operators.

Enrichment (GLE) as part of the proposed Paducah laser enrichment facility.

### China

China remains one of the largest-growing markets for nuclear power in the world. The country unveiled its 14th five-year plan, including plans for 70 GW capacity by 2025, and an estimated 120 GW by 2030 by which time it would represent 8 per cent of the country's power generation. China intends to reach peak CO2 emission before 2030 and become carbon neutral before 2060.

Further to dual-use export checks on its Generation III & IV nuclear reactor technologies, as already announced, in 2021 China adopted additional laws on exports and foreign control. A nuclear safety standardisation body was also set up to promote the 'active and orderly development' of nuclear power.

The year saw the approval of plans for four new VVER units, two at Tianwan and two at Xudabao. The first connection to the grid of Tianwan-6 was reported in May and of the high-temperature gas-cooled demonstration HTR-PM plant at Shidaowan in December. Fuqing-6, the second Chinese Hualong One reactor, achieved initial criticality, with preparations for grid connection underway. Construction also began on the two Hualong One units of Changjiang-II, with the first concrete poured for Chianjiang-3. China started construction of its SMR concept 'ACP100' on the island of Hainan.

In its technology report, the IAEA underlined China's progress in R&D for nuclear hydrogen production. Meanwhile, thanks to nuclear district heating, Haiyang became the first 'zero carbon' Chinese city.

China has uranium inventories that remain undisclosed, though domestic prospection continues. It has immense reserves of rare earth elements and very likely additional uranium resources, though possibly in remote locations and/or in phosphates.

The purchase of a 49% stake in the Ortalyk operation in Kazakhstan by CGN Mining raised its share of Kazakh uranium resources from 23 000 tonnes to 43 000 tonnes and raised the number of Kazakh mining assets with CGNPC ([77]) participation to four. It is estimated that around half of Kazakhstan's uranium production is shipped to China. Uranium imports are also regularly reported from Australia, Russia, and African and central Asian countries.

China admittedly is aiming for a closed nuclear cycle, with solutions for the recycling of spent fuel. Cooperation with European nuclear industries is a strong prospect, but earlier plans for the construction of an 800 t/year reprocessing plant using French technology have not seen any significant development lately.

In September, China and Pakistan concluded a nuclear cooperation agreement.

### Egypt

The Egyptian nuclear plants authority applied for construction permits for the VVER-1200 units at El Dabaa. As part of a long-term contract signed in 2020, TVEL's NCCP and the Egyptian atomic agency signed contractual documents for fuel deliveries to the ETRR2 research reactor.

### Ghana

A revised timetable for Ghana's first nuclear plant foresees the selection of a vendor by 2025, and generation to start from 2030.

### India

India is home to one of the world's largest thorium reserves, often in the form of monazite sands, together with other heavy minerals. It is a pioneer in the thorium fuel cycle and has several advanced facilities in that field. India is also looking to secure access to uranium, both by expanding domestic uranium mine development and via strategic participation in overseas uranium mines.

Ongoing builds made progress. Kakrapar-3, the first Indian-designed 700 MWe Indian pressurised heavy water reactor-700 (IPHWR-700), was connected to the grid, and a second 700 MWe reactor, Kakrapar-4, is expected to enter commercial operation in 2022. First concrete was poured for Kudankulam-5, with news of progress in assembling the reactor vessel.

India's electricity generation plans include the building of up to 28 new nuclear reactors in the coming decades, aiming to reach 22.5 GWe by 2031 and to supply 25% of electricity from nuclear power by 2050. Such new builds are to be done in cooperation with France, Russia and the United States. EDF already signed an agreement for the six EPR reactors to be built at Jaitapur.

### Iraq

News reports emerged about Iraqi talks with Russia's Rosatom and South Korea's KEPCO, amid plans to build up to eight nuclear reactors by 2030. Talks with the US and France have also been mentioned.

### Japan

With a complete closed fuel cycle, Japan is a major industrial and commercial player worldwide. It also leads in various fields of nuclear R&D, such as on fast reactors.

77 China General Nuclear Power Corporation.

Following the Fukushima accident, activity has slowed down, as the country's regulatory structure was completely overhauled.

A strategic energy plan, unveiled in October, underlined efforts to accelerate the restart of nuclear power plants, and announced an expansion of spent fuel storage capacity, as well as plans for thermal recycling of plutonium in at least 12 nuclear power plants by the financial year 2030. Meanwhile, the restart of the Shimane-2 unit was approved. Works on Onagawa-2 are reported to be underway, to be completed by March 2023. Following the completion of safety overhauls, Mihama-3 began operating again in June, though connection to the grid is delayed until 2022. A proposal to cancel the Tepco Ohma project met with objections.

Japan is quite active in developing and exporting nuclear technologies. In July, the Japan Atomic Energy Agency restarted its 30MWt graphite-moderated helium gas-cooled high-temperature test reactor in Oarai, envisaged to participate in hydrogen production. Mitsubishi Heavy Industries Co. Ltd is reportedly working on novel nuclear reactor designs. GE-Hitachi's SMR, BWRX-300, was selected as the SMR model for Canada's Ontario Power Generation.

On the back end, current plans are to start operating the Rokkasho reprocessing plant in financial year 2023 and the MOX fuel fabrication plants in financial year 2025. As regards fast reactors, cooperation with France and the United States is to continue, as well as the decommissioning of the Monju plant. News meanwhile emerged of delays in the start-up of the Mutsu spent fuel storage project.

### Jordan

In October, the selection of a site near Aqaba was announced for building new SMRs for power and desalination, with the help of a Korean soft loan.

Reportedly endowed with uranium-rich shales, nuclear fuel cycle developments in the country have been the subject of debate.

Jordan is the only Arab country in the region that runs a research nuclear reactor, built by a Korean KAERI-Daewoo consortium, producing Iodine-131 for nuclear medicine purposes and with work underway for Holmium-166 and Technetium-99.

### Kazakhstan

The world's leading uranium producer since 2009, accounting for over 40% of global production, Kazatomprom reported a 12% rise in production in 2021 to 21 819 tU (up from 19 477 tU in 2020), recovering from an earlier slowdown related to the COVID-19 pandemic.

Besides the IAEA LEU fuel bank, Kazakhstan is home to several nuclear fuel cycle capabilities. In November, the new ULBA-TVS fuel fabrication plant, a joint project of Kazatomprom and China's CGN, started operating after receiving delivery of low-enriched uranium. There are also reports of ongoing talks with China about a storage facility at Alashankou near the Kazakh border.

In December NuScale and the Kazakh sovereign wealth fund SKNWF signed an MoU to explore opportunities for SMRs in Kazakhstan.

### Malawi

In March, news emerged that Lotus Resources was readying the mothballed Kayelekera mine in Malawi with a view to restarting it and possibly putting Malawi back in the list of the top uranium producers. With tests of a new ore sorting technology that is expected to improve the project's economics, Lotus announced that a definitive feasibility study was underway.

### Niger

The Compagnie minière d'Akokan (Cominak) announced the closure of the Akouta mine. Meanwhile, three research permits were awarded to Société des Mines d'Azelik (Somina). New exploration permits were also granted to a joint venture between Tajia Ressources and the government.

### Norway

The year saw the conclusion of a memorandum of understanding with the US DOE to cooperate in the down-blending of HEU legacy materials in Norway. Norway's Institute for Energy Technology (IFE) announced a contract to ship unirradiated research reactor fuel to Westinghouse's Springfields plant in the UK for processing into new fuel. Sweden's Studsvik was awarded a contract to handle spent fuel from the JEEP-1 reactor currently held in the Stavbrønnen dry storage facility in Kjeller in Norway.

### Pakistan

Karachi-2 was connected to the grid, a first for a Chinese Hualong One design abroad.

### Russia

Nuclear power's share of the Russian energy sector remains at around 20%. The year was marked by the commissioning of Leningrad-6, replacing the old RBMK unit. Construction advanced on Kursk NPP-II's VVER-TOI reactors. Plans to launch the Kola-II plants were announced for 2028, using a first-of-a-kind VVER-600 design from Gidropress. Work is reportedly underway to extend Beloyarsk-3 BN-600 to 60 years. Rosenergoatom reported record levels of electricity generation in 2021 thanks to the start of Leningrad-6 and the optimisation of downtimes.

With potential for a significant increase in uranium mine production, Russia has seen increasing international involvement in areas of its fuel cycle. The country has stated its aim to increase exports, not only of nuclear power plants but also front-end fuel cycle services, thanks to the export agent Tenex and the fuel fabricator TVEL, including new enhanced accident-tolerant fuels (EATF).

Plans have been announced to revive Elkon, one of the world's largest uranium resources, among other uranium projects (see also the section on primary uranium supply). The year also saw a divestment by Tenex in Uranium One Americas shares.

Plans were also announced for additional low-power reactors in the Chukotka region as well as an ongoing project for a low-power ground-based NPP based on the RITM-200N reactor plant in Yakutia, with engineering surveys completed and the design licensed by Rostechnadzor. Four floating power units are envisaged to power the region and to provide electricity for a mining and processing plant.

Rosatom underlined Russia's plans to complete by 2030 the closure of its nuclear fuel cycle, alongside a two-component (fast and thermal) nuclear industry. Looking to develop the closed cycle and as part of the 'Breakthrough' initiative, the BREST-300 fast reactor in Seversk was licensed and construction works launched, including a nitride uranium-plutonium SNUP fuel fabrication line.

The country continues to make significant investments in R&D. The BOR-60 research reactor extended its operation. A new consortium for R&D was unveiled, amid announcements of various innovations, e.g. on the production of hafnium, high-purity scandium, and tritium, and new processes for hydrometallurgy processing and for electron-beam welding (see also the section on fuel fabrication). A new steam generation maintenance robot was also unveiled.

For medical uses, a novel Rhenium-188 generator was approved.

Abroad, various projects advanced for power plants of Russian design. First concrete was poured in Turkey at Akkuyu-3 and in China at Tianwan and Xudapu. A pressure vessel was delivered to Rooppur in Bangladesh. In India construction started at Kudankulam-5. Projects were at different stages also in Hungary, Belarus and Egypt. In Bolivia, construction began on a Russian-designed research reactor. Meanwhile, in Czechia, Rosatom was withdrawn from the Dukovany tender.

Agreements or memoranda for cooperation on the peaceful uses of nuclear energy and on R&D were concluded with Brazil Burundi, Costa Rica, Ethiopia, Nicaragua, Serbia and Zimbabwe. High-level visits and technical or training cooperation projects, including new builds and modernisation, were announced with Armenia, Bangladesh, Bolivia, Egypt, the Philippines and Rwanda. Rosatom and Brazil's IPEN signed an agreement to provide Lu-177 and other isotopes. An intergovernmental agreement on cooperation in the field of transportation of nuclear materials was signed with Belarus. Cooperation with France has been high on the agenda and a joint declaration was signed between Rosatom, EDF and CEA to cover fuel cycle R&D, including second-generation plutonium recycling.

Russia is a key supplier at various stages of the fuel cycle. TVEL/NCCP currently ensure Rosatom's position in the global market for fuel rod/assemblies thanks mainly to the captive VVER market. The Russian manufacturer announced in December that it had launched the production of a fuel assembly design (TVS-K) intended to compete in western markets to fuel Westinghouse-designed 3- and 4- loop reactors. The firm stated its intention to grow its share in the global fuel fabrication market by 2030; future developments may depend on how related security of supply questions are addressed.

### Saudi Arabia

Nuclear energy is at the centre of Saudi Arabia's Vision 2030 plans. The country currently plans to construct two nuclear power reactors and is planning to desalinate seawater using nuclear energy with the Korean SMART SMR project. Plans to make Riyadh the centre of a global mining hub were unveiled and new contracts were reportedly signed with Chinese companies for uranium exploration. It is known that there are uranium deposits in the Tabuk Basin.

### Serbia

In October, news articles reported Serbia's intentions to participate in new build projects in the region. In November, further news emerged of ongoing talks with Rosatom for a possible nuclear installation in Serbia. In December, Russia and Serbia signed an agreement for the construction of a nuclear technology centre.

### South Africa

Plans were announced for a request for proposal for a 2500 MW nuclear programme, to be issued in early 2022. Plans for a new research reactor, dubbed the Multipurpose Reactor (MPR), received cabinet approval.

### South Korea

South Korea remains one the world's most prominent nuclear energy countries, with around one third of the country's electricity produced in the 24 nuclear power reactors.

It is currently involved in the building of the first nuclear power plant in the United Arab Emirates (UAE). A teaming agreement between Korean Hydro and Nuclear Power (KHNP), KEPCO E&C, Hyundai E&C and Doosan and Petrojet was signed in 2021 for the forthcoming construction of the El Dabaa nuclear plant in Egypt.

South Korea is also exporting its technology widely. In June, KAERI and MHI signed an agreement on the development of a molten salt reactor for marine propulsion and other ends. This will take place at Gampo, where a new atomic research complex is being built. A conditional operating permit was granted for Shin-Hanul-1. Also, the construction licence for the delayed Shin-Hanul units was extended.

### Turkey

Turkey currently operates no nuclear power plants. The Akkuyu NPP project to build four VVER-1200 reactors is a first for the build-own-operate model, with the main contractor JSC Akkuyu Nuclear (99.2% owned by Rosatom) declaring its readiness to build the four units simultaneously. Turkey aims to bring Akkuyu 1 online in 2023. First concrete was poured for Akkuyu 3 and progress in manufacturing the pressure vessel was also announced. The construction licence for unit 4 was issued in October and preparatory work began on its foundations. Geotechnical studies are underway at Sinop, a possible site for a second Turkish nuclear power station

### Ukraine

Energoatom and Westinghouse signed a contract for new units at Khmelnyskyi using AP1000 technology. Energoatom is considering the Rivne, Zaporizhzhia and Orbita sites for further new builds to reach 24 GW by 2040.

Following safety upgrades funded by the European Bank for Reconstruction and Development and Euratom, lifetime extensions for some of Ukraine's 15 reactors were being considered. Adding to the list of the previous year, Zaporizhzhia-5 received a 10-year extension. After the commissioning of a fourth 750 kV overhead line, Energoatom announced a record 6 040 MWe delivered by the six units.

Westinghouse and Energoatom also signed a contract on the licensing of fuel for the Rivne units. In March, the Ukrainian regulator reported the satisfactory performance in Ukraine of the various Westinghouse TVZ-WR fuel bundles. Loading of a first experimental batch of Westinghouse VVER-440 fuel in Rivne-2 is expected in 2024. In July, Energoatom announced the delivery of Westinghouse RWFA fuel assemblies, which are planned to be loaded in Rivne-3 in 2022.

Energoatom and NuScale Power concluded a cooperation agreement to explore SMR deployment.

Permits were issued to transfer Chornobyl used fuel into a new dry storage facility, and a first storage module was filled and sealed by the IAEA.

### United Arab Emirates

An emerging customer for nuclear power, the UAE has made significant developments in recent years. In April, Barakah-1 started commercial operations. Operations also started at Barakah-2. The completion of the construction of Barakah-3, due to start-up in 2023, was also announced.

### United Kingdom

The year started with the UK signing the nuclear cooperation agreement with Euratom (see section 3.1.6). In October the UK government published its net zero strategy, which includes (i) GBP 120 million of investments from a Future Nuclear Enabling Fund (ii) a nuclear hydrogen roadmap (iii) support for SMRs and AMRs with a ten point plan for a green industrial revolution and (iv) focus on high temperature gas reactors for advanced nuclear demonstration. A consultation on proposed regulations for nuclear-powered ships was launched.

In March, Hinkley Point B units 3 and 4 received permits to resume production until the shutdown planned for July 2022, but unit 3 experienced an unplanned outage. Unit 3 of Hunterston B was permanently closed down in December. In June EDF decided to defuel and permanently shut down Dungeness B. At the same time, EDF announced that it would bring forward the end of generation operations at Heysham 2 and Torness by 2 years to 2028, while keeping the 2024 schedule for the end of production at Hartlepool and Heysham 1.

Rolls-Royce SMR Limited submitted its SMR design to the UK's generic design assessment regulatory process; a consortium announced its intention to build 16 SMRs, starting in the early 2030s.

### United States of America

Replacing the previous policy, the US administration announced a strategic vision to support the nuclear industry now and in the future. This encompasses the nuclear market and technologies, including hydrogen generation, use of accident tolerant fuel, microreactors and nuclear-renewable hybrid energy systems.

Defining 'clean energy' to include advanced nuclear systems, the American Nuclear Infrastructure Act earmarked USD 6 billion to support nuclear power plants in operation and an additional USD 2.5 billion for future reactor development. Other incentives proposed include tax production credits and USD 885 million for fusion R&D.

Among other domestic developments, the DOE announced a USD 61 million investment in advanced nuclear energy technology projects. TerraPower announced the selection of Kemmerer to site its Natrium reactor demonstrator. Four nuclear hydrogen production pilot projects using different processes were unveiled during the year, at Palo Verde, Davis-Besse, Prairie Island and Nine Mile Point. A concept paper was published for a demonstration project to integrate nuclear energy in the production of carbon-free hydrogen for direct reduction of iron ore at Zug Island, Michigan, or at Toledo, Ohio.

Further delays were announced to the Vogtle-3 and -4 nuclear power units under construction, the first US new build in decades. Also, after a court ruling, Tennessee Valley Authority withdrew plans to extend into 2022 the building permits for the mothballed Bellefonte nuclear power plant. Meanwhile, Holtec announced that it would speed up the decommissioning of the Palisades nuclear power plant.

The development and demonstration of EATF products is progressing rapidly. The DOE and Framatome signed a new four-year cooperation agreement on these fuels. Westinghouse's EnCore test rods were delivered to Oak Ridge for post-irradiation examination. The Nuclear Regulatory Commission received Westinghouse's application for the review of its advanced doped pellet technology (ADOPT™) and also approved Framatome's methodology for new fuels at higher enrichments and burnups. Framatome reported the satisfactory conclusion of tests for its EATF fuel GAIA at the Vogtle-2 nuclear power plant, becoming the first firm to complete a full cycle of ATF fuel tests. Westinghouse also announced a record initial refuelling outage at Sanmen-2 of just over 28 days.

An executive order on promoting small modular reactors was issued and a foundational initiative was unveiled to support SMR capacity-building in partner countries.

As part of the versatile test reactor project, with which Orano and Framatome are associated, the DOE announced that geotechnical works were underway. Meanwhile, Westinghouse and EDF signed a memorandum of understanding on Cobalt-60 production in select PWR reactors.

On the supply chain, the DOE invited public comments on topics related to the establishment of its USD 75 million uranium reserve program and domestic HALEU enrichment capacity (USD 500 million).

Overall, the US seems to be gearing up for a faster-paced development of nuclear technology and applications, driven not only by government action but also by private enterprise. Private capital has been showing interest not only in uranium stockpiling and advanced fission projects but also in fusion. NASA is considering a moon-based microreactor, to be launched in 2027.

## 4.2. Primary uranium supply

The following sections present an overview of the main recent developments affecting the balance of supply and demand and the status of facilities that ensure security of supply at different stages of the fuel cycle.

Uranium minerals may be categorised as primary or secondary, but 'primary' uranium supply is normally used in a different sense, to mean the uranium ore concentrates usually produced at uranium mills after they have been extracted from the earth at a uranium mine. Even if the common term 'yellow cake' is often used, uranium ore concentrates are not all the same. Data are therefore best expressed as pounds of '$U_3O_8$ equivalent' ($U_3O_8e$). Primary uranium supply should not be confused with uranium resources or uranium reserves. A coefficient must also be applied to convert pounds of triuranium octoxide ($U_3O_8$) to tonnes of elemental uranium (1000 tU is approximately 2.6 million lb $U_3O_8$).

According to the World Nuclear Association (WNA), uranium demand is projected to increase by 27% until 2030, at more than 2.6% per year, not counting life extensions, reversals of retirements, and applications other than electricity generation. In 2021 the WNA published a COP26 edition of its nuclear performance report, which also underlined the growing importance of non-power uses of nuclear energy. Unmet demand is anticipated to grow by 20% in the coming decade, with 75% of requirements worldwide after 2025 not yet contractually secured. Estimated at 128 million lb $U_3O_8$, global primary production is assessed to have fallen 68 million lb short of demand in 2021, bearing in mind ongoing Kazatomprom and Cameco production discipline, and the closure of the Cominak and Ranger mines.

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Although mining supply chains were still impacted by the COVID-19 crisis, the world saw uranium production levels increase overall. Kazatomprom reported a 12% increase in production (adding 2 342 tU to the world total). Cameco reported packaged production volume up by 22% (which added another 2.2 million lb, or 846 tU). That said, the closure in January of the Ranger uranium mine removed 1 540 tU from the total. In Niger, Cominak also announced the closure of the Akouta mine. In addition, the market saw as much as 40 million lb took off by the Sprott Physical Uranium and Yellowcake plc fund purchases. Climatic events and occasional unrest only had limited impact on production levels. Available production data therefore seems to confirm earlier estimates of a 3.1% increase in world primary uranium production in 2021.

Against this backdrop, uranium prices recovered, though observers remain cautious about the prospects. The price of uranium is for now deemed to remain subject to downside risks, though it could move onto a firmer footing, as utility demand is to rise beyond 2022.

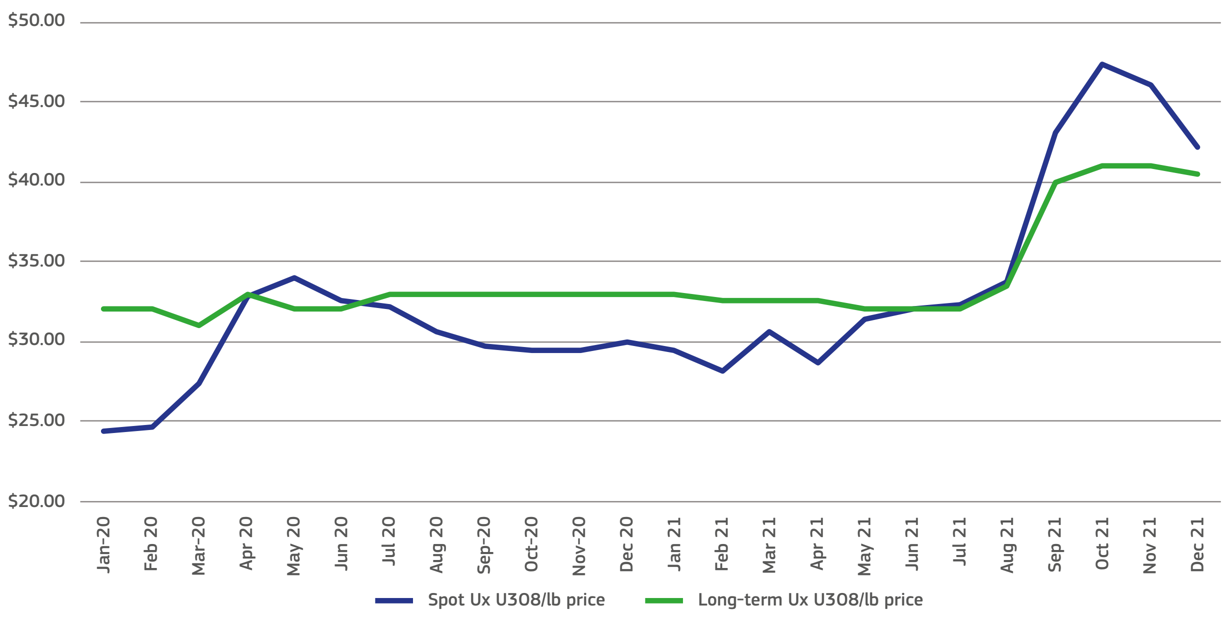
Anticipating demand and higher prices, various projects to reopen mines have been announced. In Russia, plans were announced to revive Elkon, one of the world's largest uranium resources, amid other announcements of uranium mining projects. Elsewhere, for example in Malawi, Lotus Resources announced that it is readying the mothballed Kayelekera mine, with a view to restarting it.

**Table 8. Natural uranium production in 2021 (compared to 2020, in tonnes of uranium equivalent).**

| Region/country | Production 2021 (estimate) | Share in 2021 (%) | Production 2020 (final) | Share in 2020 (%) | Change 2021/2020 (%) |
|---|---|---|---|---|---|
| Kazakhstan | 21 819 | 45.2% | 19 477 | 40.8% | 12.0% |
| Namibia | 5 753 | 11.9% | 5 413 | 11.3% | 6.3% |
| Canada | 4 693 | 9.7% | 3 885 | 8.1% | 20.8% |
| Australia | 4 192 | 8.7% | 6 203 | 13.0% | -32.4% |
| Uzbekistan | 3 500 | 7.2% | 3 500 | 7.3% | 0.0% |
| Russia | 2 635 | 5.5% | 2 846 | 6.0% | -7.4% |
| Niger | 2 248 | 4.7% | 2 991 | 6.3% | -24.8% |
| China | 1 885 | 3.9% | 1 885 | 3.9% | 0.0% |
| Others | 730 | 1.5% | 531 | 1.1% | 37.5% |
| Ukraine | 455 | 0.9% | 744 | 1.6% | -38.8% |
| South Africa | 385 | 0.8% | 250 | 0.5% | 54.0% |
| United States | 8 | 0.0% | 6 | 0.0% | 33.3% |
| **Total** | **48 303** | **100** | **47 731** | **100** | **1.2%** |

*Source: Data from the WNA and specialised publications (because of rounding, totals may not add up).*

**Figure 11. Monthly spot and term $U_3O_8$/lb prices (in USD)**




*This market price information is provided with the permission of the UxC, LLC - www.uxc.com.*

Reversing a period of contraction that began in 2016, the uranium market appears to be recovering, amid heightened investor interest. In a thinner market, spot prices rose and approached the USD 50 threshold that is often cited as the level that will incentivise projects. The $U_3O_8$ spot price increased by 40% and term prices by more than 20% year on year.

> Reversing a period of contraction that began in 2016, the uranium market appears to be recovering, amid heightened investor interest.

Going forward, higher prices would be expected to encourage mining projects. By 2024, McArthur River and Key Lake are planned to reach 60% of capacity, producing 15 million lb of uranium annually. Cigar Lake, the world's highest-grade uranium mine located in Canada, resumed its operation after uranium production at the site was suspended due to restrictions created by the COVID-19 pandemic for five months from March 2020, and for a second time in December 2021. The Canadian Nuclear Safety Commission renewed Cameco Corporation's uranium mine licence for the Cigar Lake mine, which is valid until 2031 and allows Cameco to continue operations there, which includes an underground mine and ore-processing facility as well as a surface ore load-out facility.

Besides developing ongoing projects, plans have been unveiled to accelerate the restart of Langer Heinrich (Namibia) in 2022, and to complete a feasibility study for Kayelekera in Malawi.

Nonetheless, forecasts of future demand for uranium remain uncertain, also because of secondary and other sources of uranium need to be heeded, in the medium term.

Though it is believed that there are sufficient uranium resources to support the short-term use of nuclear energy for electricity generation, there are growing indications of a probable supply gap towards the end of the decade, a risk already underlined in the 2020 OECD-NEA/IAEA red book. In the medium and long term, demand for natural uranium is expected to increase due, among other reasons, to the projected commissioning of new power plants, mostly in Asia. Applications of nuclear energy other than for power production are likely to see increased development in the coming years, possibly adding to the demand for resources. Against this backdrop, there has been renewed interest in innovative approaches to uranium recovery from low or very low-grade and unconventional resources.

After several years of low investments in resource exploration and development, the recent price rally seems to have triggered healthier levels of forward-looking disbursements. Timely investment may help ensure that uranium resources are brought to market when they are needed.

## 4.3. Secondary sources

In 2021, world primary uranium production continued to provide the bulk of world reactor requirements, complemented by secondary supply sources, which included government-held or commercial inventories of (i) natural uranium, (ii) enriched uranium, (iii) fabricated fresh fuel assemblies, (iv) down-blended uranium, (v) reprocessed uranium and plutonium recovered from spent fuel, (vi) depleted uranium, and (vii) uranium saved through underfeeding.

Typically, mined uranium only meets 70% of the utilities' requirements, the remainder being met through inventory drawdown or the use of other secondary sources of uranium. However, excess inventories are depleted or nearly so and appetite for underfeeding is falling, as enrichment capacity gets tied to new demand, and SWU prices are on the rise. The market trend is further complicated because contracts for enriched uranium product (EUP) could be replaced by separate contracts for feed, conversion and SWUs.

The role played by commercial inventories as secondary supplies remains complex, as much of the volume corresponds to materials in use by the supply chain. Past estimates of commercial inventory placed it at around 166 thousand tU ($U_3O_8$), of which 5-10% could be considered available to the spot market. The impact of such stockpiles saw a surge after Fukushima, but the resulting inventory overhang has significantly reduced since then. Substantial drawdowns have taken place and in the future they are not expected to impact the market as much as before.

There are significant government-held inventories of depleted uranium in a few countries around the world. Hexafluoride inventories are believed to be in excess of 2 million tonnes worldwide, including over 1 million tonnes in Russia alone. Though details of the US depleted uranium inventory have not been disclosed, substantial depleted uranium hexafluoride ($UF_6$) tails are reportedly held by the US DOE. The US DOE inventories at the Paducah (respectivelyPortsmouth) site alone have been estimated to produce ca. 440 (respectively 200) thousand tonnes of depleted uranium oxide at 0.2-0.4 weight-per cent uranium-235. Such depleted uranium inventories could play an increasing role as secondary supplies, depending on the change in uranium and conversion prices, compared to separative work ones.

Several governments also keep strategic stockpiles of uranium, the level of which increased after 2001 to 50-60 million lb $U_3O_8e$ (avg. 20 thousand tU). For example, the US DOE $UF_6$ strategic stocks are believed to include over 5 000 tU natural uranium. A study suggests that transfers from the US DOE stockpile could displace the market by as much as 4.2 million SWU until 2026. Plans to re-enrich part of the US Department of Energy's depleted uranium stocks are underway, and the year saw developments (see the section on enrichment) at Eunice and Piketon, as well as at Paducah where commercial operations could begin before the end of the decade. Market observers currently project US DOE surplus uranium could come on the market starting in 2027-28, offsetting as much as 2 300 tU/year.

Besides natural uranium, the US, Russian and other governments hold excess HEU stockpiles that could also displace the market in case of down-blending (also in case of dilution of 'off spec' materials). As much as 21 tU HEU is reportedly available for down-blending at the US DOE. However, such HEU inventories have many competing uses, and the availability of HEU for down-blending is expected to remain constrained. Down-blending of HEU is not restricted to the five nuclear-weapon states (NWS) countries, as a recent example (2.9 kg of HEU) in Kazakhstan shows.

When total world enrichment supply exceeds the requirements for enrichment services by a significant margin, enrichers redirect excess enrichment capacity to underfeeding and re-enrichment of tails. The post-Fukushima period has seen excess SWU capacity being used to underfeed enrichment plants and/or re-enrich depleted tails to natural uranium, leading to higher uranium inventories also in the enrichers' stores. According to the WNA, as much as 6 000 to 8 000 tU per year of natural uranium equivalent has been produced as such. However, such volumes are expected to decline, particularly if the projected surge in enrichment service demand materialises. That said, isotope separation technology is advancing rapidly, and could make such secondary supplies more attractive, in particular towards the end of the decade. For the time being, the present levels of secondary supplies have only had a limited effect in driving the conditions of the primary supply market.

Enrichment is a key part of the nuclear supply chain, and Russian enrichment facilities account for around 42% of global capacity. Excess Russian capacity has contributed significantly to underfeeding of 15 million lb $U_3O_8e$ per year. Market observers have estimated Russian volumes of underfeeding, tails re-enrichment, etc. at 5 800 tU/year, dwarfing the volume of western enrichers at around. 1 100 tU/year. Both are projected to follow a downward trend in the coming years.

Other sources to consider in secondary supplies include MOX and recycled uranium inventories, so far estimated at around 2 500 tU/year, and currently projected to increase to 4 000 tU/year by 2030. In France, for example, EDF intends to resume the use of RepU in the 4 Cruas units from 2023, and in its 1 300 MWe units from 2027 (drawing on a part of the 34 000 tU stock reportedly held in France). Russia reportedly holds 63 tonnes of separated reactor-grade plutonium, including 34 tonnes to be disposed of as MOX fuel for BN-600 and BN-800 fast neutron reactors, made at the Zheleznogorsk MOX Fuel Fabrication Facility. The WNA estimates the total inventory of such separated, recyclable materials worldwide to be in the range of 110-195 thousand tU. However, the recycling process is complex, and conversion and enrichment of recycled uranium remains a bottleneck, as few facilities are licensed to carry it out.

In the longer term, demand for high-assay LEU (HALEU) will be one of the key drivers for change, including in the secondary uranium supply market. HALEU demand is forecast to increase, starting in 2024, to exceed 40 tonnes by 2030 in the US alone, and as much as 500 tonnes (MTU) per year could be required by 2035. In light of anticipated bottlenecks at the enrichment and deconversion stages, recovery and down-blending are expected to play an important role in the future. In the United States, INL is to produce 1 tonne of HALEU per year until 2035.

> HALEU demand is forecast to increase, starting in 2024, to exceed 40 tonnes by 2030 in the US alone, and as much as 500 tonnes (MTU) per year could be required by 2035.

The down-blending of HEU sourced from EBR-II and ATR fuel would supply a total of 10 and 20 tonnes respectively. Processing at Savannah River Site is expected to process HEU in stores to deliver a further 20 tonnes. BWXT is to produce 10 tonnes by 2022 and a further 40 tonnes by 2025 from the down-blending of excess/surplus HEU. Among the alternative options, there is also talk of a 'down-blending bridge', entailing the kick-starting of an active US domestic uranium enrichment programme to replace borrowed HEU. In late 2021, the US DOE issued a request for information pointing to the possibility of setting up an HALEU fuel bank.

In the short and medium term, the availability of secondary sources of supply is therefore unlikely to continue offsetting primary uranium production as in previous years. However, the situation could change towards the end of the decade if expected transfers of surplus US DOE materials and novel isotope separation technologies materialise. That could mean increased risks of an undersupplied market in the short to medium term. Heightened demand for enriched products at higher assays (LEU+, HALEU) and rising feed prices in the coming decade could prompt a surge in investment across uranium mining, prospecting and development, as well as an expansion of uranium enrichment capacity at higher assays.

## 4.4. Uranium exploration

Expenditure on uranium mineral exploration has generally fallen in recent years. According to the NEA, reported non-domestic exploration expenditures in the OECD steeply declined from USD 420 million in 2016 to an estimated USD 54 million in 2019.

However, amid prospects of uranium markets heating up, new entrants can be expected in key uranium provinces, while existing players gear up for more ambitious exploration plans. In some key regions such as Canada, exploration spending is now projected to see a modest increase, even with seasonal effects. General exploration expenditure in Australia is also seeing a surge, amid calls for increased spending on uranium exploration in the country. Exploration is not only domestic, and Australian firms continue to lead various exploration projects in Africa.

New exploration permits in Niger are in the pipeline. Exploration in Russia is seeing significant developments, amid plans to reopen mining and geological exploration in Yakutia.

Future developments in uranium exploration will depend on multiple factors, including wider trends, as it is expected that new energy technologies and the expansion of renewable energies will prompt increases in expenditure on energy minerals exploration and production in the coming decade.

A growing number of mining sites are closing down or being placed in care and maintenance. The recent closing down of the Akouta (Niger) and Ranger (Australia) mining sites has added to a long list, which includes Rabbit Lake and McArthur River (Canada), and Langer Heinrich (Namibia). Pre-feasibility studies on the reopening of such sites had so far suggested that it was uneconomical to do so, but the recent trend in the uranium markets could change that. Orano Mining announced in late 2019 a joint venture for mining projects in Uzbekistan and stated that it was optimistic for prospects in Mongolia as well. In February, the French group announced that it had received two exploration permits for Greenland, but subsequently had to freeze its projects due to a shift in the host government stance. The group has stated that it will continue to focus exploration on Canada and Uzbekistan. Orano continues to develop projects to meet future market needs. It has kept up significant efforts in exploration and innovation to optimise projects and secure a truly diversified portfolio of assets. This includes: (i) extending the mining lifespan of south Tortkuduk (in Kazakhstan), (ii) a new heap leach pad in Somair (in Niger), (iii) three pilots (in operation, under construction or under assessment) in 2022 in Mongolia, Uzbekistan and Niger (Imouraren) (iv), exploration in Uzbekistan and Canada using SABRE extraction technology.

In spite of depressed prices, some uranium exploration and development is ongoing, both in less explored regions such as Pakistan and Brazil and in mature sites such as Canada and the United States. Extensive exploration projects have been carried out in different locations e.g. Wheeler River in Canada or the Lance uranium project in Wyoming in the United States.

## 4.5. Conversion

In the conversion sector, near-term reactor requirements in $UF_6$ are projected to remain covered by commercial inventories. By 2023, global conversion production is expected to meet the requirements arising from the ramp-up and restart of existing facilities. Nevertheless, towards 2035, new conversion assets and capacity will be needed, according to WNA estimates, as demand is expected to grow by as much as 50%, while secondary sources are projected to become scarcer. World requirements for conversion are estimated to have bottomed out at 60 million kgU in 2021 and are projected to rise to 90 million kgU by 2035. Secondary sources have so far made a significant contribution to meeting such demand, with as much as 20 million kgU in 2021, but the trend is expected to decline. Such projections assume, of course, a 'business as usual' scenario.

> Towards 2035, new conversion assets and capacity will be needed, according to WNA estimates, as demand is expected to grow by as much as 50%, while secondary sources are projected to become scarcer.

Under these assumptions, in the short- to medium- term, the global nuclear fuel market would continue to be served by the current five primary converters: Orano (France), CNNC (China), Rosatom (Russia), Cameco (Canada) and ConverDyn (United States). The world's primary nameplate conversion capacity remains estimated at 62 million kgU, not counting a possible further expansion of the French plant.

Meanwhile, Cameco moved ahead in its licence application to extend the operation of the Blind River refinery by 10 years after 2022.

At the French Malvési site, new equipment for the production of 300 tU/y of high-purity UO2 from UNH was due to enter into service in 2022. At Tricastin, business units were consolidated into the new company Orano Chimie-Enrichissement. Approval was given for the continued operation of the TU5 and W plants, as well as $U_3O_8$ storage sites. Orano confirmed the ramp-up to reach the nameplate 15 000 tU capacity of the Philippe Coste plant by 2023, amid a bullish view of the conversion market.

China's capacity is expected to grow considerably until 2025 and beyond to keep pace with domestic requirements. Projects for a 9 000 tU/y plant at Lanzhou and another 3 000 tU/y plant at Hengyang are reported to be underway.

In the United States, the DOE announced a Uranium Reserve programme to boost production and conversion capabilities. Honeywell reaffirmed its plans to restart the Metropolis Works conversion plant by 2023. In 2020, the NRC had renewed the operating licence for the plant for an additional 40 years, until 2060. Meanwhile, BWXT unveiled contingency plans to develop an alternative conversion capacity.

Compared to 2020, the COVID-19 pandemic had limited influence on operations, but like the industry in general, supply chain issues were felt.

Compared to 2020, the COVID-19 pandemic had limited influence on operations, but like the industry in general, supply chain issues were felt. Significant movement continues on the deconversion side of the industry, as Urenco's new facility in Capenhurst (UK) produced a first tanker of hydrogen fluoride (HF). The first equipment for the new French-designed W2-ECP deconversion plant was received at JSC PO ECP in Zelenogorsk (Russia). Rosatom's TVEL unveiled plans for the construction of additional similar units with the aim of eliminating depleted hexafluoride inventories by 2057. Also, MSZ in Elektrostal (Russia) announced the start of a pilot line using reductive pyrohydrolysis to process uranium hexafluoride. Deconversion of US DOE depleted uranium hexafluoride inventories at Paducah (respectively Portsmouth) was extended and is to produce ca. 440 (respectively 200) thousand tonnes of depleted uranium oxide. International Isotopes restated its interest in a future FEP deconversion plant at Hobbs, but no construction plans were announced.

**Table 9. Commercial $UF_6$ conversion facilities**

| Company | Nameplate capacity in 2020 (tU as $UF_6$) | Share of global capacity (%) |
|---|---|---|
| **Orano* (France)** | 15 000 | 24 |
| **CNNC** (China)** | 15 000 | 24 |
| **Rosatom (Russia)** | 12 500 | 20 |
| **Cameco (Canada)** | 12 500 | 20 |
| **ConverDyn*** (United States)** | 7 000 | 11 |
| **Total nameplate capacity** | **62 000** | **100** |

*Because of rounding, totals may not add up.*

*Source: www.world-nuclear.org*

** Approximate capacity installed 10 500 tU*

*** Information on China's conversion capacity is uncertain.*

**** Activity suspended since end of 2017.*

**Figure 12. Uranium conversion price trends (in USD)**


*This market price information is provided with the permission of the UxC, LLC – www.uxc.com.*

Spot conversion prices started the year oscillating around USD 20 per kgU, and fell to end the year at just over USD 16 per kgU.

Despite forthcoming changes, including the projected restart of the Metropolis plant and the completion of the ramp-up of Orano's Philippe Coste plant, conversion supply and demand are expected to remain fairly balanced. As conversion supplies remain tight, conversion prices have shown resiliency, which is expected to continue with price projections remaining in the USD 16-19 /kgU bracket.

# 4.6. Enrichment

On isotope separation, the year saw significant developments in quite different directions, most of them linked to future HALEU production needs. This focus reflects the importance of the enrichment path in that respect, alongside down-blending (see also the section on secondary sources).

In June, the US Nuclear Regulatory Commission announced that Centrus Energy Corp had been granted a licence to enrich uranium up to 20%. No other facility in the United States is currently licensed to enrich uranium to 20%. The American Centrifuge Operating LLC 16-machine demonstration cascade at Piketon is to deliver 600 kg of $UF_6$. In June, Centrus received a licence for this HALEU enrichment demonstration cascade, with production expected in 2022.

At the same time, commercial production of uranium with assays of 5% to 10% (aka LEU+) is also being envisaged by Urenco USA and by Orano. This would be a major steppingstone in HALEU production. Maximising the production of LEU+ in existing enrichment facilities is expected to lower the cost and requirements for competitive HALEU production.

Given the high transportation costs, co-location of HALEU lines for deconversion, fuel fabrication and enrichment with existing LEU+ enrichment facilities is expected to deliver the most economical solution. However the enrichment path to an HALEU-capable fuel cycle remains hampered by the lack of the significant capital investments necessary to meet enrichment, deconversion and fuel fabrication requirements, alongside complex logistical and physical security issues.

Technology developments are also underway in isotope separation, which may impact HALEU production.

Early in the year, the US government approved GE Hitachi's sale of its stake in the Wilmington-based Global Laser Enrichment licensee of the SILEX laser enrichment process, to Australia's Silex Systems Limited (51%) and Canada's Cameco Corporation (49%). GLE has plans to commercialise the technology for the re-enrichment of tails and possibly to address HALEU production.

In Russia, an upgrading of enrichment capabilities with new generation centrifuges at Zelenogorsk was announced. Rosatom had earlier published a 2030 strategy document, announcing its commitment to further develop the gas centrifuge technology, and the Zelenogorsk enrichment facility was previously designated by Rosatom for the enrichment and deconversion of HALEU, alongside fuel fabrication at NCCP in Novosibirsk, and conversion at SGChE in Seversk.

In addition to the technological developments with isotope separation technology, the year saw the granting of licences allowing enrichment plants to move to LEU+ production. Urenco USA applied to upgrade its licence to use the MCNP6 computer code for enrichments beyond 5.5 per cent (wt%) to up to 10 wt% U-235 and hinted at 'potential further enrichment increases for future activities'.

In addition to the technological developments with isotope separation technology, the year saw the granting of licences allowing enrichment plants to move to LEU+ production.

Transportation of high-assay low-enriched uranium remains a challenge and the issue of its packaging received further attention in May when ORNL released a study concluding that 30B cylinders could be approved for LEU+ (up to 10% by weight enrichment in U-235) transportation, under certain conditions. As announced earlier, in June Daher Nuclear Technologies applied for a licence for its new $UF_6$ transportation cylinder intended for HALEU, named DN-30X.

On the LEU side of the enrichment market, Brazil's INB inaugurated an extension of its Resende enrichment facility with a ninth centrifuge cascade, and signed an amendment to the existing contract that provides for the supply of ten cascades.

Overall, market actors noted that customers were more willing to enter into contracts in 2021 compared to the previous year, but observed that trade defence mechanisms targeting Russia could disrupt the market for the supply of SWUs, particularly in the US, and hence support higher prices with contract reallocation opportunities. Despite the renewal in 2020 of the suspension agreement, the annual volume of Russian SWU exports to the US is unlikely to achieve past volumes, and indeed decline. If sustained over a long period, limits on SWU imports could hamper US HALEU objectives.

**Figure 13. Monthly spot and long-term SWU prices (in USD)**


*This market price information is provided with the permission of the UxC, LLC – www.uxc.com.*

**Table 10 Operating commercial uranium enrichment facilities, with approximate 2020 capacity**

| Company | Nameplate capacity (tSW) | Share of global capacity (%) |
|---|---|---|
| **Rosatom (Russia)** | 27 654 | 46% |
| **Urenco (UK/Germany/Netherlands/ United States)** | 18 230 | 30% |
| **Orano (France)** | 7 500 | 12% |
| **CNNC (China)** | 6 750 | 11% |
| **Others * (INB, JNFL)** | 66 | 0% |
| **Total nameplate capacity** | **60 200** | **100%** |

*Because of rounding, totals may not add up.*

*Source: WNA, The Nuclear Fuel Report - Global Scenarios for Demand and Supply Availability 2019-2040.*

** INB, Brazil; JNFL, Japan*

The enrichment market in 2021 was oversupplied, with 57 million SWUs in primary supply against 52 million SWUs in demand, an imbalance aggravated by an additional 9 million SWUs in secondary supplies. Looking forward, market actors anticipate growing demand for SWUs until 2035, to reach 68 million SWUs.

Nevertheless, the spot price began 2021 in the range of 50-55 USD/SWU but reached 56 USD/SWU at the end of the year. Term prices followed a parallel trend, suggesting the market is now over its low point of 2017. Projections suggest a rising trend, possibly hitting 70 USD/SWU by 2025.

# 4.7. Fuel fabrication

Around the world, several fuel manufacturers reported intensified efforts in R&D, design and the production of innovative fuels.

## Improving production lines

Various announcements concerned the expansion or improvement of fuel production lines.

Cameco applied for a licence to expand its Port Hope CANDU fuel fabrication facility, increasing UO2 production capacity to 1650 tonnes from the current 1500. TRIGA International's fuel fabrication plant at Romans (France) completed the major renovation works that began in 2014; regulatory go-ahead is expected. The year saw the first delivery of LEU from the uranium enrichment centre in Novouralsk, intended for the Ulba-TVS plant in Kazakhstan. Rosatom and Framatome signed an agreement for long-term cooperation to develop fuel production technologies and in other related fields. Construction of the mixed nitride uranium-plutonium fuel (SNUP) fabrication line at Seversk began. Following safety checks, Mitsubishi announced plans to resume fuel manufacturing at the Tokai plant. JNFL is also considering the restart of the Rokkasho MOX fuel fabrication facility.

## SMR and research reactor fuel

Several announcements were made on future production of SMR and/or HALEU fuels, as well as on fuels for research reactors.

Canadian Nuclear Laboratories announced the first production of proprietary TRISO pellets for Ultra Safe Nuclear Corporation's micro modular reactor, planned for Chalk River. Framatome in France and Lightbridge in the US agreed to dissolve their 'Enfission' joint venture on innovative fuel designs. The US company announced its intention to prioritise opportunities with SMRs in the near term. Centrus and Oklo signed a letter of intent on the production of metallic HALEU fuel for Oklo's Aurora fast neutron reactor. The first batch of fuel elements were loaded in the Shidaowan high-temperature gas-cooled demonstration unit (HTR-PM) under construction in China. BWXT was awarded by the NNSA a USD 17.9 million contract to complete the second phase of the construction of a previously announced research reactor U-Mo HALEU fuel fabrication line. This fuel is intended to make it easier to convert research reactors from using HEU.

## MOX

Some significant developments during the year concerned mixed oxide fuels and fuels for fast reactors.

A batch of MOX fuel manufactured by Orano was delivered to Japan's Takahama-3 and -4, the third to be delivered since the Fukushima accident. At Seversk, first concrete was poured for the demonstration complex of the fast neutron reactor BRES-OD-300, comprising a fuel fabrication facility scheduled to start producing the new mixed uranium nitride-plutonium fuel (MNUP) in 2023. First generation MNUP fuel was developed by VNIINM and tested at Beloyarsk BN-600. An experimental assembly for the 55 MW RITM-200N reactor was announced by MSZ (MC3, also known as Elemash) in Elektrostal, intended for plants in the Arctic region. Pilot REMIX fuel at Balakovo-3 was unloaded (to be examined in 2023) and the REMIX-TVS fuel fabrication plant at Seversk's CXK began operating.

A first batch of TVS-2M assemblies was completed with uranium-plutonium pellets made at Zheleznogorsk and loaded into Balakovo-1. An additional set of 180 assemblies of TVS-MOX fuel manufactured at Zheleznogorsk were loaded into BN-800 at Beloyarsk-4, which is expected to be fully loaded with MOX fuel in 2022. Contracts were signed at Novosibirsk to supply fuel for the ETRR-2 research reactor. Construction of a facility at Elektrostal was started, to fabricate fuel for the CFR-600 Beloyarsk fast reactor twin being constructed at Xiapu in China. Other research and development efforts were announced for fuels for new icebreakers, low-power mobile reactors, and new floating nuclear power plants.

As part of major fiscal support in the 'France Relance' plan, new multiannual programmes were approved, whereby MOX fuel would also be used to fuel several 1 300 MWe units. The French MOX fabrication plant Melox is expected to receive investments accordingly. Separately, plans were announced to resume the use of RepU from 2023 in the 4 Cruas units, and from 2027 in 1300MWe units (see also the section on secondary sources).

## Enhanced accident-tolerant fuel

A significant number of other key developments in the year concerned enhanced accident-tolerant fuels.

Since the 2018 field test at the Hatch plant (United States), the development of enhanced accident-tolerant fuels has accelerated worldwide. Both evolutionary fuels (doped pellets with chromium coating cladding, for example) and advanced fuels (SiC/SiC cladding for example) are being developed. Preparing for the expected licensing applications and the commercial introduction of EATF fuels, in August the NRC released new data to update safety evaluation computer codes.

> The year saw the first ever loading of a complete lead test assembly made from enhanced accident-tolerant fuel rods.

The year saw the first ever loading of a complete lead test assembly made from enhanced accident-tolerant fuel rods, with the loading of Framatome's ProTect assembly in unit 2 of the Calvert Cliffs nuclear power plant (United States). As part of the Euratom R&D programme, a call was launched that included funding for the development of enhanced accident-tolerant fuels. Westinghouse announced that several test rods with the EATF EnCore Fuel technology arrived at ORNL in support of licensing efforts for the firm's EATF fuel design.

Four EnCore lead test assemblies manufactured by ENUSA Industrias Avanzadas had been loaded at Doel-4 (Belgium) the year before, becoming the first insertion of enhanced accident-tolerant EnCore Fuel rod assemblies in Europe. A pilot operation with new EATF chromium-enhanced TVS-2M fuel started at Rostov-2. At JSC VNIINM, tests continued of enhanced accident-tolerant uranium disilicide fuels, while tests of enhanced accident-tolerant claddings and uranium-molybdenum alloy fuels for both PWR and VVER were carried out at JSC's SSC RIAR plant in Dimitrovgrad. The Luch Institute announced an experimental fuel using a uranium alloy with zirconium iodide. Irradiation trials of fuel assemblies with the new enhanced accident-tolerant fuel previously unveiled by TVEL began at the Rostov nuclear power plant.

## Other fuel market developments

Various announcements were also made in 2021 on fuel enhancements and market developments.

The Novosibirsk Chemical Concentrates Plant (NZHK PJSC) announced the launch of a facility to produce TVS-Kvadrat fuel for Westinghouse-design 3- and 4- loop PWR reactors, following tests at Sweden's Ringhals-3, and examinations at Studsvik. TVEL has previously stated its aim to gain 22% of the fuel market by 2030, with help from a consortium including GE-Hitachi (GEH) and Global Nuclear Fuel-Americas (GNF-A).

In the wake of contracts awarded by TVA to Framatome in 2020, April saw the novel use of four 3D-printed channel fasteners installed on Atrium-10XM assemblies loaded in TVA's Browns Ferry 2 during the planned outage, where they joined lead test Atrium-11 assemblies to prepare the transition to the new fuel design.

TVEL announced the successful completion of a fifth irradiation cycle at Kola-4 of their third-generation nuclear fuel design RK-3 for VVER-440 reactors, a prototype of the forthcoming RK-3+ design. TVEL is reportedly working on several parallel projects to deliver this new nuclear fuel, primarily aimed at foreign customers. The new fuel, which is expected to be ready in batch quantity by 2023, allows the reactor to operate with increased thermal capacity and to extend the fuel cycle at the plant, leading to greater economic efficiency.

Meanwhile, Westinghouse WRFA assemblies (VVER-1000) were delivered to Ukraine's Rivne-3 plant, part of an effort to achieve a full core by 2025. Westinghouse and Energoatom signed a contract to supply fuel assemblies for the two 440 MWe units of the Rivne station. Plans include manufacturing at the firm's Swedish plant, with the first test assemblies to be delivered at Rivne-2 in 2024.

Following the completion of irradiation tests at Balakovo power station and the commissioning of a pilot fuel production line at the Siberian Chemical Combine in Seversk, TVEL announced that a first batch of uranium-plutonium REMIX nuclear fuel for

VVER-1000 reactors has been manufactured in cooperation with the Mining and Chemical Combine in Zheleznogorsk and that it had successfully passed acceptance. The development of REMIX fuel is to be completed by 2023.

## 4.8. Reprocessing and recycling

The uranium still present in spent fuel can be recovered, becoming reprocessed uranium. During the irradiation of uranium fuel, some plutonium is also generated, and this is also recovered at the reprocessing stage. By using reprocessed uranium and recovered plutonium, utilities can significantly reduce their need for fresh uranium. Governments can also use this material as a strategic stockpile.

The year saw many developments relating to the back end of the fuel cycle, in several EU countries, Canada, Japan, Russia and the United States.

In Russia, spent fuel from Lepse was transferred for processing at Mayak. A contract was signed to deal with the waste from the '310' facilities at Angarsk. The setup of a waste accountancy system was announced, and TVEL was designated as the central organisation for waste management. TVEL signed agreements with Czechia's Skoda and with the French companies D&S Groupe and Robatel, for cooperation - along with other industries - on the back end of the fuel cycle, and SGChE JSC at Seversk got approval to produce 'regenerated' uranium for EDF.

In Europe, hearings were held by the French relevant authorities on the upgrades planned by Orano for UP2-800 and UP-3A, to make it possible to process fuels with up to 10% in U-235, from both LW and HW cycles. A public consultation on the final dismantling of the Brennilis heavy water reactor opened in November. Meanwhile a decree was passed on the decommissioning of the 'Atelier d'uranium enrichi'. Also, Germany's Nukem technologies, in a consortium with Uniper Anlagenservice, finished dismantling Barsebek-1 in Sweden. Excavation of the first final disposal tunnel at Onkalo in Finland began. A study by Studsvik AB shows that all of Norway's metallic uranium research fuel liabilities could be processed within 2 years for disposal in an underground repository. Some R&D projects have begun to explore possible unconventional uses of spent nuclear fuel, for example in a nuclear biorefinery.

In the US, the NRC announced it would stop its work on a spent fuel reprocessing rule. A new uranium reclamation furnace at Y-12 was announced, to start in 2026. In Canada, Ontario Power Generation announced a project with Moltex to demonstrate the technical viability of a new process to recycle used CANDU fuel.

In Japan, JNFL applied for a licence for upgrades to its Rokkasho-mura reprocessing plant and to the nearby MOX fuel fabrication facility. The Japanese Federation of Electric Power Companies released a plutonium utilisation plan that explained which plants which are to participate in pluthermal power generation, along with operation plans for the Rokkasho reprocessing plant and for the MOX fuel fabrication plant which forecast that reprocessing operations would start in 2023 and MOX fabrication in 2025. News emerged of delays in the Mutsu used fuel storage facility project, now expected for 2023.

The process of removing all 566 fuel assemblies from the storage pool of unit 3 at the damaged Fukushima Daiichi nuclear power plant in Japan was completed by March 2021. In April, the Japanese government announced its decision that the treated water stored at the Fukushima Daiichi site will be discharged into the sea; in November Tepco released the results of a radiological impact assessment of this action. In April, the regulator approved Tepco's plan to decommission the four BWRs at Fukushima Daiini, 11 km south of the damaged Fukushima Daiichi plant. The process, which will involve the construction of a dry spent fuel storage on site, is expected to be completed by 2064. Japanese news media reported on the ongoing literature survey on two Hokkaido locations, Suttu and Kamoennai, to assess whether they have a site that is potentially suitable for a deep geological repository.

The generation of spent fuel worldwide is estimated to be around 10 000 – 13 000 tHM/y. Global commercial reprocessing capacity is just over 2 000 tHM/y. Reprocessing is mainly carried out in La Hague, France, which has a capacity of 1 700 tHM/y, and in Chelyabinsk, Russia, which has a capacity of 400 tHM/y. There are plans to increase capacity in Russia to 600 tHM/y by 2022. The Japanese Rokkasho plant, whose postponed operation seems now to come nearer, would add 800 tHM/y to global commercial capacity.

The most profitable way of using the fissile materials bred in the course of power production in the existing light-water nuclear reactors will be as fast reactor fuel. On a worldwide scale, however, the lack of installed fast reactor capacity has meant that in some cases it has been considered advantageous to recycle these materials in light-water reactors.

Uranium and plutonium recycling has therefore been carried out, mainly via the use of mixed oxide (MOX) fuels, in several countries, including Belgium, France, Japan and Switzerland. By the start of 2021, experience with MOX recycling in both thermal reactors and in fast neutron reactors had been gained in more than 60 reactors worldwide.

Second-generation recycling, that is recycling of irradiated MOX fuels, is possible and has been undertaken on a large scale. However, this has been subject to certain technical constraints and efforts are underway to make improvements. The Euratom R&D programme has recently published calls for proposals to that effect.

In the meantime, new technical solutions (REMIX) have been proposed that would make the multiple recycling of uranium and plutonium in thermal reactors easier. The recent start of a pilot fuel fabrication line (see MOX section in "Fuel fabrication" chapter) or such fuels could open new recycling perspectives in the future.

Recent announcements in France, Japan and Russia of efforts to optimise the recycling of uranium and plutonium in existing light-water reactors should be underlined. However, the number of plants licensed for MOX use remains limited. Likewise, very few fuel fabrication plants are capable of manufacturing such fuels. In the EU, MOX fuel is commercially produced in the Melox plant in Marcoule, France, with an authorised production capacity of only 195 tHM/y. Outside the EU, MOX fuel is commercially produced in Zheleznogorsk, Russia.

**Work of trucks and the excavator in an open pit**

*©evgenii_v - stock.adobe.com*

# 5. Management

### Legal status

The Supply Agency was endowed by the Euratom Treaty ([78]) with legal personality and financial autonomy ([79]) and operates under the supervision of the European Commission on a non-profit-making basis. The Statutes ([80]) set out the governance of the Agency in more detail.

ESA's headquarters have been in Luxembourg since 2004. Together with the Commission, ESA has concluded a seat agreement with the government of the Grand Duchy of Luxembourg.

ESA is 100% financed from the EU's general budget.

## 5.1. Budgetary and financial management

Part of ESA's operating costs is financed by its own budget, with the remainder directly financed by the Commission.

ESA carries out its financial operations according to the relevant provisions of its Statutes and of the EU Financial Regulation ([81]) as well as the accounting rules and methods decided on by the Commission.

The Commission adopts ESA's budget, transfers the contribution allocated under the EU budget, and directly covers some of its administrative costs.

### Budget

The Agency's budget for 2021 ([82]) amounted to EUR 210 000, 9% less than 2020 (EUR 230 000).

Revenue and expenditure were in balance. ESA's revenue derived entirely from a contribution from the EU budget. ([83]).

The operating costs that ESA paid for from its budget include work travel, development of the NOEMI nuclear IT system for contract management and a stand-alone computer centre, advisory commmittee meetings, conferences, media subscriptions, publications and communication activities.

On 31 December 2021, ESA's accounts showed a budget execution of EUR 209 489.28, or 99.76% of commitment appropriations. The budget and final annual accounts have been published on ESA's website ([84]).

### In-kind contribution from the Commission

A large part of ESA's administrative expenses are covered directly by the Commission's budget, including salaries ([85]), premises, infrastructure, training, and some IT services and equipment.

In an internal estimate for 2021, the salaries of the Agency's staff were calculated at EUR 1 784 258, while other costs covered by the Commission amounted to EUR 486 000. This expenditure and the associated transactions are not included in ESA's accounts but in the Commission section of the EU's annual accounts. In 2021, ESA did not pay charge-back on any baseline services provided to it by the Commission ([86]).

The in-kind contribution and charge-back exemption has had a positive impact on ESA's administrative capacity.

### Financial accounts

In 2021, the assets owned by the Agency totalled EUR 963 933 (EUR 963 505 in 2020). They were financed by liabilities of EUR 99 442 (10%) and equity of EUR 864 491 (90%).

78 Article 52 of the Euratom Treaty.
79 Article 54 of the Euratom Treaty.
80 Council Decision (2008/114/EC, Euratom) of 12 February 2008 establishing Statutes for the Euratom Supply Agency.
81 Regulation (EU, Euratom) 2018/1046 on the financial rules applicable to the general budget of the Union; Article 68 of the EU Financial Regulation stipulates its applicability to the implementation of the budget for ESA.
82 C(2020) 8593 of 10.12.2020.
83 ESA's present financial situation results from the 1960 Council decision to postpone indefinitely the introduction of a charge on transactions (contracts for the purchase of nuclear materials by EU utilities), which had been intended to cover ESA's operating costs.
84 https://euratom-supply.ec.europa.eu/about-esa/financial-autonomy_en.
85 Salaries are paid by the Commission in line with Article 4 of ESA's Statutes and are not charged to the Agency's budget.
86 Commission Decision C(2018) 5120, Annex 21.

The Agency has a capital of EUR 5 856 000. An instalment of 10% of the capital has been paid by each Member State. On 31 December 2021, the total amount of instalments called up and reported in ESA's accounts stood at EUR 518 400 ([87]).

In 2021, fixed assets increased by 44% to EUR 277 256 (EUR 191 937 in 2020) following the continued development of the NOEMI IT system ([88]), classified as an internally generated intangible asset, and its going into production in December 2021.

# 5.2. Human resources

## Staff allocation

ESA staff are Commission civil servants (officials) and ESA's establishment plan is incorporated into the global staff numbers of the Commission.

In 2021, one person was recruited and one retired. At the end of 2021, the Agency had 16 staff (8 administrator and 8 assistant posts) and one vacant assistant post under recruitment.

| Human Resources | 2021 | |
|---|---|---|
| **Number of staff** | **Authorised under the EU Budget ([89])** | **Number of personnel ([90])** |
| **Commission officials** | 17 | 15.5 |
| AD official or temporary agent | 7 | 7.1 |
| AST official or temporary agent | 10 | 8.4 |
| **Total establishment plan posts** | **17** | **15.5** |
| **Contract agents** | 0 | 0 |
| **Seconded national experts** | 0 | 0 |
| **Total staff** | **17** | **15.5** |

The difficulties in recruitment had a negative effect on staffing: 15.5 posts were filled throughout the year, compared to 17 posts contained in the establishment plan. Despite the Agency's efforts, it proved extremely difficult to find assistants at lower grades, given the specialised profile required and the associated pay levels compared to the cost of living in Luxembourg. The Commission's Directorate-General for Energy, to which ESA staff are administratively attached, helped by upgrading one assistant post to administrator in 2021. This resulted in a successful selection and recruitment procedure.

## Equal opportunities

ESA provides equal career opportunities for staff at all levels and promotes a gender-balanced workplace. Women make up 56% of ESA staff and men 44%. This equal opportunities policy is also reflected in management positions, which are also equally distributed.

87 The amount still to be aligned with the UK's withdrawal from the EU and Euratom. UK's participation, as a Member State, in the capital of the Euratom Supply Agency amounted to EUR 672 000 of which 10% is held in the Agency's bank account. No relevant provision exists in the Withdrawal Agreement or in any other agreement or arrangement or legal act, to date. The Agency, which cannot act unilaterally in this field, has registered an accounting provision in its financial statements on the UK's share repayment.

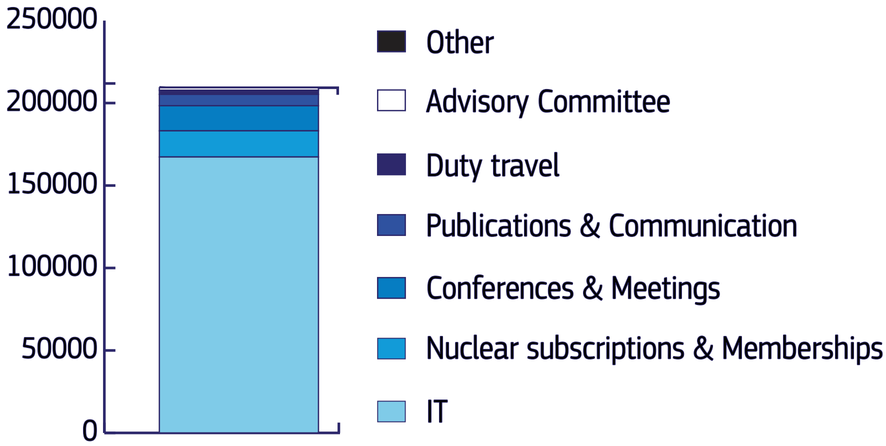
88 The NOEMI IT system (Nuclear Observatory and ESA Management of Information) envisages the management of ESA business core, i.e. nuclear supply contracts and EU security of supply information (see 5.4 below).

89 EU General Budget 2021, OJ L 57, 27.2.2020 p.1978, footnote 2.

90 Posts actually filled throughout the year.

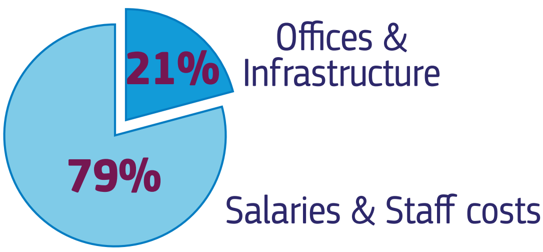
# ESA Resources


## ESA Budget
**EUR 210 000**



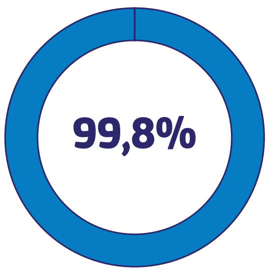

## European Commission
(in-kind contribution)

**EUR 2 270 258**




## Budget Implementation

**EUR 209 489**



# 5.3. Information management and communication

## NOEMI Information system

Since January 2020, the Agency has been developing new software to support the management of ESA's core tasks under the Treaty and the ESA Statutes. The NOEMI IT system ('Nuclear Observatory and ESA Management of Information') started operation in December 2021. The capitalised cost of phase one of the system amounted to EUR 269 466.69.

At this first stage, NOEMI constitutes a secure integrated database of information from contracts for the supply of nuclear materials and for related services, and of data provided by the nuclear users through annual reporting. To this end, it supports the monitoring of the EU's nuclear fuel cycle supply market and transactions, and makes it possible to export data to produce analyses and reports.

The system will further evolve in the coming years to increase ESA's efficiency and effectiveness. In the next stage, expected to start in 2022, it will integrate business workflows, monitor operations and improve the user experience. The project's final stage will eventually enable ESA to fully and securely digitalise its operations, which comprise handling nuclear fuel cycle contracts and collecting and processing data on the nuclear materials and fuel market.

> NOEMI will improve ESA's ability to monitor the nuclear materials and fuel market while securely hosting sensitive data on nuclear contracts.

## Information security

To carry out its mission, ESA receives or collects data from nuclear market actors, and processes, analyses, and, if appropriate, publishes them. ESA does this in full compliance with applicable confidentiality requirements. As records held by the Agency on its work under Chapter VI of the Treaty contain business secrets and sensitive information about companies, they must not be disclosed to other legal persons. The Agency premises, provided by the Commission, have reinforced security. All members of staff of the Agency and all external contractors hold security clearance. The NOEMI IT system underwent a vulnerability assessment, which will be repeated after all the recommendations from this assessment are carried out.

## Communication and visibility

https://euratom-supply.ec.europa.eu/index_en

Euratom Supply Agency
@Euratom_supply

EURATOM Supply Agency

The Agency carries out its own communication and outreach policy.

In 2021, in collaboration with the Commission's Directorate-General for Communication, ESA revamped its website, which is now harmonised with that of the Commission. The website is hosted on an updated dynamic platform and is more user-friendly. Taking advantage of the website upgrade, all the information posted there was redrafted for a better user experience.

ESA continued to engage in targeted outreach to stakeholders in industry, research, and national administrations to ensure business continuity during the COVID-19 pandemic.

# 5.4. Audit and discharge

## Audit by the European Court of Auditors

The European Court of Auditors (ECA) audits ESA's financial and budgetary accounts and the underlying transactions each year, in line with internationally accepted public sector auditing standards. ECA's responsibility is to give the European Parliament and the Council a statement of assurance as to the reliability of the annual accounts and the legality and regularity of the underlying transactions.

ESA duly notes ECA's observations and takes the necessary measures. It also carefully follows the observations of a cross-cutting nature that accompany the ECA annual report on the EU agencies.

ECA signed off the Agency's 2020 accounts and issued a 'clean' opinion both on the accounts and on the legality and regularity of revenue and expenditure transactions ([91]). ECA noted a high carry-over rate of payment appropriations, mainly IT service contracts that had been signed in 2020 but not completed by the end of the year. ESA explained the carry-over by the need to ensure continuity and the timely delivery of the business-critical project, NOEMI.

Following up on observations made in previous years, ECA closed a comment on the high cancellation rate of carried-over budget appropriations, as ESA had taken steps to monitor its budget execution more closely.

### Discharge

The discharge authority for ESA is the European Parliament, acting on a Council recommendation. The European Parliament granted ESA's Director-General a discharge for the implementation of the budget for the 2019 financial year ([92]).

## 5.5. Internal control and assurance

### Internal control and risk management

The Agency's internal control framework is designed to provide reasonable assurance in achieving the five objectives set out in Article 36 of the Financial Regulation, on the internal control of operations and budget implementation.

In 2021, ESA performed a risk assessment update covering all areas of the Agency's work and its operational and administrative processes. Adjustments were made to align the controls in place with the risks.

### Management assurance

ESA carries out an assessment of the effectiveness of its internal controls. This consists of an evaluation of pre-defined monitoring indicators, including a survey; the evaluation of audit results and new or outstanding recommendations; and an analysis of non-compliances and exception cases.

The annual assessment for 2021 did not reveal any risks that could lead to a reservation in the Annual Declaration of Assurance.

Based on aspects of the internal control systems and the assurance they provide – the building blocks of assurance – the Director-General was in a position, as the authorising officer, to sign the Declaration of Assurance ([93]) that accompanies this annual report.

### Business continuity

The COVID-19 pandemic continued to affect the EU in 2021. With the lessons learned from 2020, the Agency remained fully operational and demonstrated it could respond swiftly to the challenges arising from this health crisis.

In line with Commission guidance and to minimise the risk to staff and their families, ESA introduced teleworking as the default option. Critical and essential staff who needed to access resources and work on the premises were able to do so on rotation.

No reduction of revenue, asset value or budget took place in 2021. ESA introduced changes to its spending pattern through a budget amendment and internal transfers. It reduced spending on statutory work trips and Advisory Committee meetings, and invested in its IT system instead.

In its 2022 work programme, ESA revised its tasks where appropriate and adjusted timeline to take account of changing circumstances.

## 5.6. Improving effectiveness and efficiency

Given ESA's limited resources, it is of paramount importance to ensure that it remains effective and efficient. The Agency is committed to continuously improving how it works. However, the number of tasks and the expectations of stakeholders continue to grow.

Repeated efforts have been made to achieve efficiency gains and reallocate human resources to new and upcoming tasks. This allowed the Agency to carry out the tasks linked to increasing legal obligations despite a reduction in the human resources that were allocated ([94]). In particular, it has created and continued to run the nuclear market observatory (a new task in the 2008 Statutes), fulfilled the obligations of financial autonomy ([95]) and assumed responsibility for the supply of

91 Annex 9 – ECA audit report 2020.
92 European Parliament Decision of 13/5/2020: P9_TA-(2021)0195 – Decision 2020/2171(DEC).
93 Annex 10 – Declaration of Assurance of the Director General for the year 2021.
94 The Agency has been working with the current staff level (17 officials) since 2012, when it lost one administrator (AD) post. In 2015, it also lost contractual agent allocation.
95 Financial autonomy was reinstated in 2012, after the European Parliament noted that the lack of autonomous budget between 2008 and 2012 and de facto integration in the Commission was at odds with the Agency's Statutes. Financial autonomy requires the Agency to employ a full-time accounting officer and undergo an extensive annual audit by ECA.

medical radioisotopes ([96]). Since 2020, it has had to fulfil the tasks related to public access to documents and personal data protection without the support that was previously given by the Commission.

Further efficiency gains are possible by developing the NOEMI IT system, subject to the resources available. Introducing the internal workflow, planned for Phase 2 ([97]), will streamline the process of handling information from contracts within the deadlines. ESA has already started to receive digitally signed contracts that would allow full electronic handling of this procedure. A future Phase 3 could envisage a portal for market participants to digitally exchange contracts and data with the Agency, subject to additional security measures. That would constitute a decisive benefit for utilities and industry.

Another source of efficiency gains could be further synergies with the Commission, through specialised support functions, e.g. treasury, accounting officer and information security officer services, and extending the use of corporate tools, e.g. to manage work-related travel.

*©Zdenek Venclikc - stock.sdobe.com*

96 'Towards the secure supply of radioisotopes for medical use in the EU' 3053rd Employment, Social Policy Health and Consumer affairs Council meeting, 6 December 2010 and 17453/12, ATO 169/ SAN 321, 7 December 2012.

97 The exact timing and budget of Phase 2 of the NOEMI project will be decided in 2022 and submitted to the Commission's IT and Cybersecurity Board.

# 6. Contact information

### ESA address for normal correspondence and registered letters

European Commission
EURATOM SUPPLY AGENCY
Euroforum Building
L - 2920 Luxembourg
LUXEMBOURG

### ESA address for express delivery companies or messengers

European Commission
Euratom Supply Agency
MERCIER Building - To the attention of “TRI CENTRAL”
(Phone: + 352 4301 44442)
2, rue Mercier
L-2144 Luxembourg
LUXEMBOURG

### Office address

Complexe Euroforum
1, rue Henri M. Schnadt
L-2530 Luxembourg
LUXEMBOURG

Tel. +352 4301-34294

### Email

ESA-AAE@ec.europa.eu

### Twitter

@Euratom_supply

### Website

This report and previous editions are available on ESA’s website: https://euratom-supply.ec.europa.eu/index_en

A limited number of paper copies of this report can be obtained, subject to availability, from the address listed above.

### Further information

Additional information: http://europa.eu

Europa provides access to the websites of the European institutions and other bodies.

More information on the Commission’s Directorate-General for Energy: http://ec.europa.eu/energy. This website contains information on areas such as security of energy supply, energy-related research, nuclear safety, and liberalisation of the electricity and gas markets.

# 7. Annexes

## Annex 1
## EU-27 gross and net requirements (quantities in tU and tSW)

*(A) 2022-2031*

| Year | Natural uranium | | Separative work | |
|---|---|---|---|---|
| | Gross requirements | Net requirements | Gross requirements | Net requirements |
| **2022** | 13 001 | 12 293 | 11 073 | 10 488 |
| **2023** | 12 586 | 11 519 | 10 776 | 10 026 |
| **2024** | 11 912 | 10 063 | 10 261 | 9 061 |
| **2025** | 12 588 | 11 329 | 10 951 | 9 799 |
| **2026** | 13 167 | 11 693 | 11 350 | 10 027 |
| **2027** | 11 828 | 10 081 | 10 301 | 8 745 |
| **2028** | 12 395 | 10 539 | 10 826 | 9 144 |
| **2029** | 11 919 | 9 636 | 10 242 | 8 185 |
| **2030** | 11 711 | 9 527 | 10 014 | 8 011 |
| **2031** | 11 120 | 8 597 | 9 424 | 7 112 |
| **Total** | **122 225** | **105 277** | **105 217** | **90 598** |
| **Average** | **12 223** | **10 528** | **10 522** | **9 060** |

*(B) Extended forecast 2032-2041*

| Year | Natural uranium | | Separative work | |
|---|---|---|---|---|
| | Gross requirements | Net requirements | Gross requirements | Net requirements |
| **2032** | 11 615 | 9 246 | 9 861 | 7 677 |
| **2033** | 10 069 | 7 534 | 8 477 | 6 152 |
| **2034** | 10 377 | 7 512 | 8 756 | 6 090 |
| **2035** | 10 020 | 6 986 | 8 389 | 5 580 |
| **2036** | 9 878 | 7 026 | 8 305 | 5 651 |
| **2037** | 9 418 | 6 402 | 7 893 | 5 100 |
| **2038** | 10 020 | 7 183 | 8 479 | 5 840 |
| **2039** | 8 988 | 6 158 | 7 593 | 4 961 |
| **2040** | 9 765 | 6 943 | 8 208 | 5 583 |
| **2041** | 9 528 | 6 705 | 7 946 | 5 321 |
| **Total** | **99 677** | **71 695** | **83 906** | **57 954** |
| **Average** | **9 968** | **7 170** | **8 391** | **5 795** |

# Annex 2
# Fuel loaded into EU-27 reactors and deliveries of fresh fuel under purchasing contracts

| Year | Fuel loaded | | | Deliveries | | |
|---|---|---|---|---|---|---|
| | LEU (tU) | Feed equivalent (tU) | Enrichment equivalent (tSW) | Natural U (tU) | % spot | Enrichment (tSW) |
| 1980 | | 9 600 | | 8 600 | (*) | |
| 1981 | | 9 000 | | 13 000 | 10.0 | |
| 1982 | | 10 400 | | 12 500 | < 10.0 | |
| 1983 | | 9 100 | | 13 500 | < 10.0 | |
| 1984 | | 11 900 | | 11 000 | < 10.0 | |
| 1985 | | 11 300 | | 11 000 | 11.5 | |
| 1986 | | 13 200 | | 12 000 | 9.5 | |
| 1987 | | 14 300 | | 14 000 | 17.0 | |
| 1988 | | 12 900 | | 12 500 | 4.5 | |
| 1989 | | 15 400 | | 13 500 | 11.5 | |
| 1990 | | 15 000 | | 12 800 | 16.7 | |
| 1991 | | 15 000 | 9 200 | 12 900 | 13.3 | 10 000 |
| 1992 | | 15 200 | 9 200 | 11 700 | 13.7 | 10 900 |
| 1993 | | 15 600 | 9 300 | 12 100 | 11.3 | 9 100 |
| 1994 | 2 520 | 15 400 | 9 100 | 14 000 | 21.0 | 9 800 |
| 1995 | 3 040 | 18 700 | 10 400 | 16 000 | 18.1 | 9 600 |
| 1996 | 2 920 | 18 400 | 11 100 | 15 900 | 4.4 | 11 700 |
| 1997 | 2 900 | 18 200 | 11 000 | 15 600 | 12.0 | 10 100 |
| 1998 | 2 830 | 18 400 | 10 400 | 16 100 | 6.0 | 9 200 |
| 1999 | 2 860 | 19 400 | 10 800 | 14 800 | 8.0 | 9 700 |
| 2000 | 2 500 | 17 400 | 9 800 | 15 800 | 12.0 | 9 700 |
| 2001 | 2 800 | 20 300 | 11 100 | 13 900 | 4.0 | 9 100 |
| 2002 | 2 900 | 20 900 | 11 600 | 16 900 | 8.0 | 9 500 |
| 2003 | 2 800 | 20 700 | 11 500 | 16 400 | 18.0 | 11 000 |
| 2004 | 2 600 | 19 300 | 10 900 | 14 600 | 4.0 | 10 500 |
| 2005 | 2 500 | 21 100 | 12 000 | 17 600 | 5.0 | 11 400 |
| 2006 | 2 700 | 21 000 | 12 700 | 21 400 | 7.8 | 11 400 |
| 2007 (**) | 2 809 | 19 774 | 13 051 | 21 932 | 2.4 | 14 756 |
| 2008 (**) | 2 749 | 19 146 | 13 061 | 18 622 | 2.9 | 13 560 |
| 2009 (**) | 2 807 | 19 333 | 13 754 | 17 591 | 5.2 | 11 905 |
| 2010 (**) | 2 712 | 18 122 | 13 043 | 17 566 | 4.1 | 14 855 |
| 2011 (**) | 2 583 | 17 465 | 13 091 | 17 832 | 3.7 | 12 507 |
| 2012 (**) | 2 271 | 15 767 | 11 803 | 18 639 | 3.8 | 12 724 |

| Year | Fuel loaded | | | Deliveries | | |
|---|---|---|---|---|---|---|
| | LEU (tU) | Feed equivalent (tU) | Enrichment equivalent (tSW) | Natural U (tU) | % spot | Enrichment (tSW) |
| **2013 (**)** | 2 343 | 17 175 | 12 617 | 17 023 | 7.1 | 11 559 |
| **2014 (**)** | 2 165 | 15 355 | 11 434 | 14 751 | 3.5 | 12 524 |
| **2015 (**)** | 2 231 | 16 235 | 11 851 | 15 990 | 5.0 | 12 493 |
| **2016 (**)** | 2 086 | 14 856 | 11 120 | 14 325 | 3.1 | 10 775 |
| **2017 (**)** | 2 232 | 16 084 | 12 101 | 14 312 | 3.8 | 10 862 |
| **2018 (**)** | 1 763 | 15 912 | 13 580 | 12 835 | 5.0 | 10 899 |
| **2019 (**)** | 2 129 | 14 335 | 10 880 | 12 835 | 9.6 | 12 912 |
| **2020 (**)** | 1 908 | 13 124 | 9 988 | 12 592 | 3.0 | 11 224 |
| **2021 (**)** | **2 197** | **15 401** | **11 588** | **11 975** | **4** | **10 290** |

*(*) Data not available*
*(**) The LEU fuel loaded and feed equivalent contain Candu fuel.*
*Before 2021: data for EU-27 + UK*
*2021: data for EU-27*

# Annex 3
# ESA average prices for natural uranium

| Year | Multiannual contracts | | Spot contracts | | New multiannual contracts | | Exchange rate |
|---|---|---|---|---|---|---|---|
| | EUR/kgU | USD/lb $U_3O_8$ | EUR/kgU | USD/lb $U_3O_8$ | EUR/kgU | USD/lb $U_3O_8$ | EUR/USD |
| **1980** | 67.20 | 36.00 | 65.34 | 35.00 | | | 1.39 |
| **1981** | 77.45 | 33.25 | 65.22 | 28.00 | | | 1.12 |
| **1982** | 84.86 | 32.00 | 63.65 | 24.00 | | | 0.98 |
| **1983** | 90.51 | 31.00 | 67.89 | 23.25 | | | 0.89 |
| **1984** | 98.00 | 29.75 | 63.41 | 19.25 | | | 0.79 |
| **1985** | 99.77 | 29.00 | 51.09 | 15.00 | | | 0.76 |
| **1986** | 81.89 | 31.00 | 46.89 | 17.75 | | | 0.98 |
| **1987** | 73.50 | 32.50 | 39.00 | 17.25 | | | 1.15 |
| **1988** | 70.00 | 31.82 | 35.50 | 16.13 | | | 1.18 |
| **1989** | 69.25 | 29.35 | 28.75 | 12.19 | | | 1.10 |
| **1990** | 60.00 | 29.39 | 19.75 | 9.68 | | | 1.27 |
| **1991** | 54.75 | 26.09 | 19.00 | 9.05 | | | 1.24 |
| **1992** | 49.50 | 24.71 | 19.25 | 9.61 | | | 1.30 |
| **1993** | 47.00 | 21.17 | 20.50 | 9.23 | | | 1.17 |
| **1994** | 44.25 | 20.25 | 18.75 | 8.58 | | | 1.19 |
| **1995** | 34.75 | 17.48 | 15.25 | 7.67 | | | 1.31 |
| **1996** | 32.00 | 15.63 | 17.75 | 8.67 | | | 1.27 |
| **1997** | 34.75 | 15.16 | 30.00 | 13.09 | | | 1.13 |
| **1998** | 34.00 | 14.66 | 25.00 | 10.78 | | | 1.12 |
| **1999** | 34.75 | 14.25 | 24.75 | 10.15 | | | 1.07 |
| **2000** | 37.00 | 13.12 | 22.75 | 8.07 | | | 0.92 |
| **2001** | 38.25 | 13.18 | (*) 21.00 | (*) 7.23 | | | 0.90 |
| **2002** | 34.00 | 12.37 | 25.50 | 9.27 | | | 0.95 |
| **2003** | 30.50 | 13.27 | 21.75 | 9.46 | | | 1.13 |
| **2004** | 29.20 | 13.97 | 26.14 | 12.51 | | | 1.24 |
| **2005** | 33.56 | 16.06 | 44.27 | 21.19 | | | 1.24 |
| **2006** | 38.41 | 18.38 | 53.73 | 25.95 | | | 1.26 |
| **2007** | 40.98 | 21.60 | 121.80 | 64.21 | | | 1.37 |
| **2008** | 47.23 | 26.72 | 118.19 | 66.86 | | | 1.47 |
| **2009** | 55.70 | 29.88 | 77.96 | 41.83 | (**) 63.49 | (**) 34.06 | 1.39 |
| **2010** | 61.68 | 31.45 | 79.48 | 40.53 | 78.11 | 39.83 | 1.33 |
| **2011** | 83.45 | 44.68 | 107.43 | 57.52 | 100.02 | 53.55 | 1.39 |
| **2012** | 90.03 | 44.49 | 97.80 | 48.33 | 103.42 | 51.11 | 1.28 |
| **2013** | 85.19 | 43.52 | 78.24 | 39.97 | 84.66 | 43.25 | 1.33 |
| **2014** | 78.31 | 40.02 | 74.65 | 38.15 | 93.68 | 47.87 | 1.33 |

| Year | Multiannual contracts | | Spot contracts | | New multiannual contracts | | Exchange rate |
|---|---|---|---|---|---|---|---|
| | EUR/kgU | USD/lb $U_3O_8$ | EUR/kgU | USD/lb $U_3O_8$ | EUR/kgU | USD/lb $U_3O_8$ | EUR/USD |
| **2015** | 94.30 | 40.24 | 88.73 | 37.87 | 88.53 | 37.78 | 1.11 |
| **2016** | 86.62 | 36.88 | 88.56 | 37.71 | 87.11 | 37.09 | 1.11 |
| **2017** | 80.55 | 35.00 | 55.16 | 23.97 | 80.50 | 34.98 | 1.13 |
| **2018** | 73.74 | 33.50 | 44.34 | 20.14 | 74.19 | 33.70 | 1.18 |
| **2019** | 79.43 | 34.20 | 55.61 | 23.94 | 80.00 | 34.45 | 1.12 |
| **2020** | 71.37 | 31.36 | (***) | (***) | 75.51 | 33.17 | 1.14 |
| **2021** | **89.00** | **40.49** | **(***)** | **(***)** | **92.75** | **42.17** | **1.18** |

*(*) The spot price for 2001 was calculated based on an exceptionally low total volume of only 330 tU covered by four transactions.*

*(**) ESA's price method took account of the ESA 'MAC-3' new multiannual $U_3O_8$ price, which includes amended contracts from 2009 onwards.*

*(***) In 2020, the ESA $U_3O_8$ spot price was not calculated because there were not enough transactions (less than 3) to calculate the index.*

*Before 2021: data for EU-27 + UK*

*2021: data for EU-27*

# Annex 4
# Purchases of natural uranium by EU utilities, by origin, 2012-2021 (tU)

| Country | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Niger** | 2 376 | 2 235 | 2 171 | 2 077 | 3 152 | 2 151 | 2 067 | 1 962 | 2 555 | 2 905 |
| **Kazakhstan** | 2 254 | 3 612 | 3 941 | 2 949 | 2 261 | 2 064 | 1 754 | 2 518 | 2 414 | 2 753 |
| **Russia** | 5 102 | 3 084 | 2 649 | 4 097 | 2 765 | 2 192 | 1 759 | 2 543 | 2 545 | 2 358 |
| **Australia** | 2 280 | 2 011 | 1 994 | 1 910 | 1 896 | 2 091 | 1 909 | 1 851 | 1 671 | 1 860 |
| **Canada** | 3 212 | 3 156 | 1 855 | 2 845 | 2 946 | 4 099 | 3 630 | 1 485 | 2 312 | 1 714 |
| **Re-enriched tails** | 0 | 0 | 0 | 212 | 212 | 171 | 161 | 161 | 196 | 196 |
| **EU** | 421 | 421 | 397 | 412 | 220 | 0 | 18 | 251 | 64 | 163 |
| **South Africa** | 412 | 17 | 20 | 1 | 0 | 0 | 118 | 115 | 21 | 21 |
| **Namibia** | 1 350 | 716 | 325 | 385 | 504 | 923 | 1 046 | 1 234 | 481 | 5 |
| **Malawi** | 180 | 115 | 125 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Uzbekistan** | 159 | 653 | 365 | 526 | 115 | 348 | 166 | 612 | 329 | 0 |
| **Other** | 256 | 621 | 299 | 229 | 130 | 80 | 80 | 103 | 4 | 0 |
| **United States** | 241 | 381 | 586 | 343 | 125 | 193 | 110 | 0 | 0 | 0 |
| **Ukraine** | 0 | 0 | 23 | 0 | 0 | 0 | 19 | 0 | 0 | 0 |
| **HEU feed** | 395 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total** | **18 639** | **17 023** | **14 751** | **15 990** | **14 325** | **14 312** | **12 835** | **12 835** | **12 592** | **11 975** |

*Before 2021: data for EU-27 + UK*

*2021: data for EU-27*

# Annex 5
# Use of plutonium in MOX in the EU-27 and estimated natural uranium and separative work savings

| Year | kg Pu | Savings | |
|---|---|---|---|
| | | tNatU | tSW |
| **1996** | 4 050 | 490 | 320 |
| **1997** | 5 770 | 690 | 460 |
| **1998** | 9 210 | 1 110 | 740 |
| **1999** | 7 230 | 870 | 580 |
| **2000** | 9 130 | 1 100 | 730 |
| **2001** | 9 070 | 1 090 | 725 |
| **2002** | 9 890 | 1 190 | 790 |
| **2003** | 12 120 | 1 450 | 970 |
| **2004** | 10 730 | 1 290 | 860 |
| **2005** | 8 390 | 1 010 | 670 |
| **2006** | 10 210 | 1 225 | 815 |
| **2007** | 8 624 | 1 035 | 690 |
| **2008** | 16 430 | 1 972 | 1 314 |
| **2009** | 10 282 | 1 234 | 823 |
| **2010** | 10 636 | 1 276 | 851 |
| **2011** | 9 410 | 824 | 571 |
| **2012** | 10 334 | 897 | 622 |
| **2013** | 11 120 | 1 047 | 740 |
| **2014** | 11 603 | 1 156 | 825 |
| **2015** | 10 780 | 1 050 | 742 |
| **2016** | 9 012 | 807 | 567 |
| **2017** | 10 696 | 993 | 691 |
| **2018** | 8 080 | 726 | 510 |
| **2019** | 5 241 | 470 | 331 |
| **2020** | 5 308 | 481 | 340 |
| **2021** | **4 859** | **439** | **311** |
| **Grand total** | **238 215** | **25 922** | **17 588** |

*Before 2021: data for EU-27 + UK*

*2021: data for EU-27*

# Annex 6
# EU nuclear utilities that contributed to this report

| |
|---|
| ČEZ, a.s. |
| EDF |
| EnBW Kernkraft GmbH |
| ENUSA Industrias Avanzadas, S.A., S.M.E |
| EPZ |
| Fortum Power and Heat Oy |
| Ignalina NPP |
| Kozloduy NPP Plc |
| Nuklearna elektrarna Krško, d.o.o. |
| Oskarshamn NPP (OKG) |
| Paks NPP Ltd |
| PreussenElektra (formerly E.ON Kernkraft GmbH) |
| RWE Power AG |
| Slovenské elektrárne, a.s. |
| Societatea Nationala Nuclearelectrica S.A. |
| Synatom sa |
| Teollisuuden Voima Oyj (TVO) |
| Vattenfall Nuclear Fuel AB |

# Annex 7
# Uranium suppliers to EU utilities

| |
|---|
| BHP Billiton |
| Cameco Inc. USA |
| Cameco Marketing INC. |
| CNU-SA |
| Internexco |
| Itochu International Inc |
| KazAtomProm |
| Macquarie Bank Limited, London branch |
| NUKEM GmbH |
| Orano Cycle |
| Orano Mining |
| Peninsula |
| Rio Tinto Marketing Pte Ltd |
| Tenex (JSC Techsnabexport) |
| TVEL |
| Uranium One |
| Urenco Ltd |

# Annex 8 Calculation method for ESA's average $U_3O_8$ prices

## ESA price definitions

To provide reliable objective price information comparable with previous years, only deliveries made to EU utilities or their procurement organisations under purchasing contracts are taken into account for calculating the average prices.

In the interests of market transparency, ESA calculates three uranium price indices on an annual basis:

1. The ESA spot $U_3O_8$ price is a weighted average of $U_3O_8$ prices paid by EU utilities for uranium delivered under spot contracts during the reference year.

2. The ESA multiannual $U_3O_8$ price is a weighted average of $U_3O_8$ prices paid by EU utilities for uranium delivered under multiannual contracts during the reference year.

3. The ESA 'MAC-3' multiannual $U_3O_8$ price is a weighted average of $U_3O_8$ prices paid by EU utilities, but only under multiannual contracts which were concluded or for which the pricing method was amended in the previous 3 years (i.e. between 1 January 2019 and 31 December 2021) and under which deliveries were made during the reference year. In this context, ESA considers amendments as separate contracts, if the amendments directly affect the prices paid.

To ensure statistical reliability (sufficient amounts) and safeguard the confidentiality of commercial data (i.e. ensure that details of individual contracts are not revealed), ESA price indices are calculated only if there are at least five relevant contracts.

In 2011, ESA introduced its quarterly spot $U_3O_8$ price, an indicator published on a quarterly basis if EU utilities have concluded at least three new spot contracts.

All price indices are expressed in US dollars per pound (USD/lb $U_3O_8$) and euro per kilogram (EUR/kgU).

## Definition of spot vs multiannual contracts

The difference between spot and multiannual contracts is as follows:

- spot contracts provide either for one delivery only or for deliveries over a maximum of 12 months, whatever the time between conclusion of the contract and the first delivery;

- multiannual contracts provide for deliveries extending over more than 12 months.

The average spot-price index reflects the latest developments on the uranium market, whereas the average price index of uranium delivered under multiannual contracts reflects the average multiannual price paid by European utilities.

## Methodology

The methodology applied has been discussed and agreed in the Advisory Committee working group.

## Data collection tools

Prices are collected directly from utilities or via their procurement organisations on the basis of:

- contracts submitted to ESA;

- end-of-year questionnaires – backed up, if necessary, by visits to the utilities.

## Data requested on natural uranium deliveries during the year

The following details are requested: ESA contract reference number, quantity (kgU), delivery date, place of delivery, mining origin, obligation code, natural uranium price specifying the currency, unit of weight (kg, kgU or lb), chemical form ($U_3O_8$, $UF_6$ or $UO_2$), whether the price includes conversion and, if so, the price and currency of conversion, if known.

## Deliveries taken into account

The deliveries taken into account are those made under natural uranium purchasing contracts to EU electricity utilities or their procurement organisations during the relevant year. They also include the natural uranium equivalent contained in enriched uranium purchases.

Other categories of contracts, e.g. those between intermediaries, for sales by utilities, purchases by non-utility industries or barter deals, are excluded. Deliveries for which it is not possible to reliably establish the price of the natural uranium component are also excluded from the price calculation (e.g. uranium out of specification or enriched uranium priced per kg EUP without separation of the feed and enrichment components).

## Data quality assessment

ESA compares the deliveries and prices reported to the data collected when the contracts are concluded, taking into account any subsequent updates. In particular, it compares the actual deliveries to the 'maximum permitted deliveries' and options. Where discrepancies appear between maximum and actual deliveries, the organisations concerned are asked to clarify.

## Exchange rates

To calculate the average prices, the original contract prices are converted into euro per kgU contained in $U_3O_8$, using the average annual exchange rates published by the European Central Bank.

## Prices which include conversion

For the few prices which include conversion but where the conversion price is not specified, given the relatively minor cost of conversion, ESA converts the $UF_6$ price into a $U_3O_8$ price. It does so by using an average conversion value based on reported conversion prices under the natural uranium multiannual contracts.

## Independent verification

Two members of ESA's staff independently verify spreadsheets from the database.

As a matter of policy, ESA never publishes a corrective figure, should errors or omissions be discovered.

## Data security

Confidentiality and physical protection of commercial data is guaranteed by appropriate measures.

# Annex 9
# ECA audit report 2020

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# 3.32. Euratom Supply Agency (ESA)

## Introduction

**3.32.1.** The Euratom Supply Agency ("the Agency", or ''ESA''), located in Luxembourg, was created in 1958[203]. Council Decision 2008/114/EC, Euratom[204], replaced the preceding Statutes of the Agency. The Agency's main task is to ensure there is a regular supply of nuclear materials, in particular nuclear fuels, to EU users, by means of a common supply policy based on the principle of equal access to sources of supply. *Figure 3.32.1* presents key figures for the Agency[205].

### Figure 3.32.1 – Key figures for the Agency


* Budget figures are based on the total payment appropriations available during the financial year.

** "Staff" includes EU officials, EU temporary agents, EU contract staff and seconded national experts, but excludes interim workers and consultants.

*Source:* Annual accounts of the Agency for the financial year 2019 and Final annual accounts of the Agency for the financial year 2020; Staff figures provided by the Agency.

## Information in support of the statement of assurance

**3.32.2.** The audit approach taken by the ECA comprises analytical audit procedures, direct testing of transactions and an assessment of key controls of the Agency's supervisory and control systems. This is supplemented by evidence provided by the work of other auditors and an analysis of information provided by the Agency's management.

**3.32.3.** Please refer to section 3.1 of the report for the description of the basis for the opinion, responsibilities of management and those charged with governance and the auditor's

[203] OJ 27, 6.12.1958, p. 534/58.

[204] OJ L 41, 15.2.2008, p. 15.

[205] More information on the Agency's competences and activities is available on its website: http://ec.europa.eu/euratom/index.html.

responsibilities for the audit of the accounts and underlying transactions. The signature on page *341* forms an integral part of the opinion.

## The Court's statement of assurance provided to the European Parliament and the Council – Independent auditor's report

## Opinion

**3.32.4.** We have audited:

(a) the accounts of the Euratom Supply Agency which comprise the financial statements[206] and the reports on the implementation of the budget[207] for the financial year ended 31 December 2020 and

(b) the legality and regularity of the transactions underlying those accounts,

as required by Article 287 of the Treaty on the Functioning of the European Union (TFEU).

### Reliability of the accounts

#### Opinion on the reliability of the accounts

**3.32.5.** In our opinion, the accounts of the Agency for the year ended 31 December 2020 present fairly, in all material respects, the financial position of the Agency at 31 December 2020, the results of its operations, its cash flows, and the changes in net assets for the year then ended, in accordance with its Financial Regulation and with accounting rules adopted by the Commission's accounting officer. These are based on internationally accepted accounting standards for the public sector.

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[206] The financial statements comprise the balance sheet, the statement of financial performance, the cash flow statement, the statement of changes in net assets and a summary of significant accounting policies and other explanatory notes.

[207] The reports on implementation of the budget comprise the reports which aggregate all budgetary operations and the explanatory notes.

## Legality and regularity of the transactions underlying the accounts

### Revenue

**Opinion on the legality and regularity of revenue underlying the accounts**

**3.32.6.** In our opinion, the revenue underlying the accounts for the year ended 31 December 2020 is legal and regular in all material respects.

### Payments

**Opinion on the legality and regularity of payments underlying the accounts**

**3.32.7.** In our opinion, the payments underlying the accounts for the year ended 31 December 2020 are legal and regular in all material respects.

**3.32.8.** The observations which follow do not call the ECA's opinion into question.

## Observations on budgetary management

**3.32.9.** Carry-overs of committed appropriations were high for Title II (administrative expenditure): they amounted to €177 445, or 80 % of the ESA's appropriations for the entire Title. The carry overs were partially due to the effects of the Covid-19 pandemic.Nearly half (46 % ) of the amount carried over from 2020 to 2021 was intended to be used for IT services provided in 2021. This creates risks on the implementation of the payment appropriations of 2021 considering that in the previous years there was high cancellation rate.

The ESA should have used its 2021 budget for those services. In order to respect the principle of annuality, the ESA should further improve its budget planning and its implementation cycles.

## Follow-up of previous years' observations

**3.32.10.** An overview of the action taken in response to the ECA's observations from previous years is provided in the *Annex*.

## Annex – Follow-up of previous years' observations

| Year | ECA's observations | Action taken to respond to ECA's observations (Completed / Ongoing / Outstanding / N/A) |
|---|---|---|
| **2018** | The cancellation rate of budget appropriations carried over from 2017 to 2018 is high, at 21 %, demonstrating unjustified commitments in the previous year. | **Completed** |





# The Agency's reply

**3.32.9.** The Noemi project constitutes an investment (EUR 355 000 over 2019-2021) into IT application that will allow the Agency to securely hold and process sensitive data on nuclear contracts. The project replies to the repeated Discharge Authority requests to continue the digitalisation in order to cut down on bureaucracy.

The commitment in December 2020 ensured the continuity of the team to implement the approved project plan.

The Agency recognises the risks connected with the implementation and will proactively ensure monitoring of the project to its delivery.

# Annex 10
# Declaration of assurance

Ref. Ares(2022)4690437 - 27/06/2022
With qualified electronic signature(s)

Euratom Supply Agency

Director-General

## DECLARATION OF ASSURANCE

I, the undersigned, Agnieszka Ewa Kaźmierczak

Director-General of the Euratom Supply Agency in 2021

In my capacity as authorising officer

- Declare that the information contained in Chapters 1 and 5 of this report, forming the annual activity report, gives a true and fair view ([1]);
- State that I have reasonable assurance that the resources assigned to the activities described in this report have been used for their intended purpose and in accordance with the principles of sound financial management, and that the control procedures put in place give the necessary guarantees on the legality and regularity of the underlying transactions.

This reasonable assurance is based on my own judgement and on the information at my disposal, such as the results of the self-assessment and the lessons learned from the reports of the Court of Auditors for several years prior to the year of this declaration.

I confirm that I am not aware of anything not reported here which could harm the interests of the Euratom Supply Agency.

Qualified electronic signature by:
AGNIESZKA EWA KAZMIERCZAK
Date: 2022-06-27 15:30:40 +02:00

Agnieszka Ewa Kaźmierczak

1 True and fair in this context means a reliable, complete and correct view on the state of affairs in the Agency.

# Annex 11
# Work Programme 2022

## Mission and Objectives

In line with the Euratom Treaty and its own Statutes, the mission of the Supply Agency of the European Atomic Energy Community (‘ESA’) is to maintain a regular and equitable supply of nuclear materials (ores, source materials and special fissile materials) for all users in the Community.

ESA’s strategic objective is the security of supply of nuclear materials, particularly nuclear fuel, for power and non-power uses, by means of the common supply policy.

In line with ESA’s strategic objective, the following specific medium-term objectives have been established:

### Specific policy objectives

1. ensure continuous supply of nuclear materials for users in the Community in the short and medium term;

2. facilitate the future supply and encourage the diversification and emergence of reliable alternative sources of nuclear fuel supply, services and design;

3. facilitate the continued and equitable supply of medical radioisotopes;

4. provide the Community with expertise, information and advice on the nuclear materials and services market;

### Specific supporting objectives

5. pursue contacts with EU and international authorities, international organisations, utilities, industry and nuclear organisations to further the objectives of ESA;

6. further improve the effectiveness and efficiency of ESA’s organisation and operations.

This work programme sets out the main activities to be pursued in 2022.

The strategic priority, general and specific objectives, and activities have been linked to ensure that all actions contribute to the achievement of these objectives and to the achievement of the high-level priorities. It takes due account of the priorities, policies and objectives set out by the Commission.

## Areas of activity

### Activity I. Contract management

ESA’s main task is to ensure regular and equal access to supplies of nuclear materials for all users in the Community. To this end, it uses its right of option on nuclear materials produced in the Community Member States and its exclusive right to conclude contracts for supply of nuclear materials, coming from inside or outside the Community and it keeps track of transactions related to services in the nuclear fuel cycle.

To facilitate the operations of the common market for the nuclear materials and fuels, ESA will:

1. assess and conclude, as appropriate, nuclear material supply contracts, pursuant to Article 52 of the Euratom Treaty, in line with the common supply policy, taking due account of the European energy security strategy;

2. review and acknowledge notifications of transactions involving small quantities, pursuant to Article 74 of the Euratom Treaty;

3. review and acknowledge notifications of transactions for the provision of services in the nuclear fuel cycle, pursuant to Article 75 of the Euratom Treaty, in line with the common supply policy, taking due account of the European energy security strategy;

4. implement the Rules that determine the manner in which demand is to be balanced against the supply of ores, source materials and special fissile materials;

5. provide information and support to stakeholders on contract issues related to the nuclear common supply policy and/or the Agency’s Rules;

6. support the Commission’s nuclear materials accountancy, on request, in verifying contract data contained in prior notifications of movements of nuclear materials;

7. contribute, on request, for matters within its purview, to the assessment of international agreements communicated to the Commission under Article 103 of the Treaty.

### Activity II. Facilitating future supply

ESA takes responsibility for the common supply policy with the strategic objective of security of supply in order to prevent excessive dependence of Community users on any single external supplier, service provider or design through appropriate diversification, in line with relevant decisions at political level.

To facilitate future supply, ESA will:

1. help strengthen clarity to market actors on the common supply policy pursued by ESA;

2. advocate and encourage emergence of alternative sources of nuclear fuel supply, services and design where such sources are presently not available, in particular for VVER reactors.

### Activity III. Facilitating the continued and equitable supply of medical radioisotopes

In order to enhance the security of supply of Molibdenum-99/Technetium-99m and possibly other radioisotopes that are indispensable for nuclear medicine procedures, the Supply Agency has been entrusted with the monitoring role for the supply chain of medical radioisotopes in the EU. ESA, jointly with the industry association Nuclear Medicine Europe (NMEu), chairs the European Observatory on the Supply of Medical Radioisotopes.

ESA will contribute to implementation of the action plan of the Commission's SAMIRA initiative (Strategic Agenda for Medical Ionising Radiation Applications of nuclear and radiation technology).

ESA will:

1. lead and coordinate the activities of the European Observatory on the Supply of Medical Radioisotopes;

2. continuously monitor the needs for HEU and HALEU for the production of medical radioisotopes and for fuelling research reactors;

3. undertake measures that facilitate future supply of high-enriched uranium (HEU);

4. explore, assess and propose ways to ensure supply of high-assay low-enriched uranium (HALEU) for production of medical radioisotopes and as fuel for research reactors;

5. explore ways of monitoring and forecasting the supply of a wide range of radioisotopes, as provided for in the SAMIRA action plan;

6. encourage (particularly in the context of the Euratom research and training programme) projects to secure fuel supply for research reactors and the production of medical radioisotopes.

### Activity IV. Provision of expertise, information and advice on the nuclear materials and services market

Entrusted with the role of the Nuclear Fuel Market Observatory, ESA will continue to monitor the nuclear fuel and services market and relevant research and innovation activities to identify trends likely to affect the EU's security of supply. It will continue to produce analyses and reports.

The Agency's ambition is to maintain its position as a reliable and well-respected source of high-quality and neutral analyses of the Euratom nuclear fuel cycle market.

To deliver on its market monitoring responsibilities, ESA will:

1. monitor and analyse market conditions and technological developments which are likely to have an impact on the nuclear fuel market;

2. conduct the annual survey and deliver the market analysis as part of its annualrReport;

3. support the activities of the Advisory Committee's working groups;

4. publish and disseminate information, including through yearly natural uranium price indices, reports, studies, newsletters, timely updates on ESA's website and through the Advisory Committee or other meetings.

### Activity V. Cooperation with stakeholders and partners

To efficiently carry out its tasks and contribute to security of supply, ESA will actively pursue its relations with EU and Euratom institutions and agencies, Member State authorities, operators, the research community and industry, and international players.

In particular, ESA will:

1. cooperate with the Commission on common supply policy matters;

2. liaise with the operators and other concerned parties to encourage and facilitate diversification;

3. in cooperation with the Euratom Member States concerned, coordinate the implementation of the memorandum of understanding with the US Department of Energy - National Nuclear Security Administration, in order to facilitate supply of HEU, until full conversion of the reactors and processes using it, and to advance towards the minimisation of HEU;

4. engage with interested parties in and outside the EU, both suppliers and users, to:

a. facilitate the continued supply of medical radioisotopes, and

b. meet the needs of HALEU;

5. maintain regular contact with:

a. international nuclear organisations such as the IAEA and the OECD NEA;

b. other international players on the nuclear fuel market, including through membership of the World Nuclear Association, the European Nuclear Society and the World Nuclear Fuel Market;

c. medical radioisotopes supply chain stakeholders (industry, research and user organisations);

6. contribute to monitoring the implementation of the Euratom cooperation agreements with non-EU countries as regards trade in nuclear materials.

### Activity VI. Making ESA's internal organisation and operations more effective

ESA keeps its procedures under review to further improve the management of the contracts it receives and the operations of its Nuclear Market Observatory. Given ESA's limited resources, it is of paramount importance to ensure that ESA remains effective and efficient.

To this end, ESA will focus its attention on:

1. ensuring compliance and effective internal control;
2. ensuring sound financial management;
3. ensuring competent, engaged and effectively utilised workforce;
4. keeping its work practices under review and updating them where appropriate;
5. progressive implementation of ESA's document management and security policy;
6. progressive implementation of the IT system supporting the work of ESA (NOEMI - Nuclear Observatory and ESA Management of Information).

# List of tables



# List of figures

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Euratom Supply Agency

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