Euratom Supply Agency Annual Report 2023

Luxembourg: Publications Office of the European Union, 2024

Print	ISBN 978-92-68-19320-4	ISSN 0257-9138	doi:10.2833/855043	KO-AA-24-001-EN-C
PDF	ISBN 978-92-68-19321-1	ISSN 1683-3481	doi:10.2833/060459	KO-AA-24-001-EN-N

Photo credits

Cover page: Energy and health campus, Petten (NL) © NRG PALLAS

Chapter 1
Page 8: Control room panel © Slovenské elektrárne

Chapter 2
Page 24: Fuel rack © Slovenské elektrárne
Page 30: Enusa Juzbado Facility © Enusa, Industrias Avanzadas, S.A., S.M.E.

Chapter 3
Page 31: RRF EPZ turbine © Ruden Riemens Fotografie
Page 35: Borssele NPP © Ruden Riemens Fotografie
Page 36: European Nuclear Energy Forum © Euratom Supply Agency
Page 38: Vacuum vessel sectors at ITER © ITER Organization
Page 40: Euratom Research in Action and Opportunities for Europe © DG RTD
Page 50: Mochovce November 2023 © Euratom Supply Agency
Page 53: XIX Plenary meeting of the European Observatory on the Supply of Medical Radioisotopes © Nuclear Medicine Europe
Page 56: Orano Stable Isotopes Laboratory © Orano, CRESPEAU CYRIL
Page 57: Delivery of IBA Cyclone 30XP cyclotron to the Radioisotope Centre POLATOM, National Centre for Nuclear Research in Poland © NCBJ
Page 58: Energy and health campus, Petten (NL) © NRG PALLAS

Chapter 4
Page 66: Fuel rod © Slovenské elektrárne

Chapter 5
Page 70: ESA Advisory Committee meeting December 2023 © Euratom Supply Agency
Page 72: High Level Workshop on security of supply of medical radioisotopes © Euratom Supply Agency
Page 73: ESA Annual Report 2022 © Euratom Supply Agency
Page 75: Participants of the XX Plenary of MR Observatory at EC DG JRC in Karlsruhe DE © European Union 2023
Page 76: World Nuclear Fuel Cycle Conference © Euratom Supply Agency
Page 77: ESA in EANM Annual Conference 2023 © Euratom Supply Agency

Chapter 6
Page 79: ESA offices in Luxembourg © Euratom Supply Agency
Page 83: Enusa Juzbado facility © Enusa, Industrias Avanzadas, S.A., S.M.E.

Foreword

I am writing these introductory words as the new Director General of the Euratom Supply Agency, a role which I have taken up on 1 May 2024.

The Agency finds itself in a complex and challenging environment. In 2023, the nuclear supply market continued to face supply uncertainties linked to the impact of the war of aggression in Ukraine and the need to diversify from Russian supply and a changing geopolitical environment. At the same time, plans in some countries to extend or expand nuclear power generation, the emergence of innovative designs such as Small and Advanced Modular Reactors, but also the growing interest in the use of radioisotopes for medical purposes, are changing the supply landscape for nuclear material in Europe.

In this situation of change and uncertainty, the Euratom Supply Agency continues to play its central role – ensuring the security of supply of nuclear materials – by using its legal prerogatives, by providing reliable market analysis and by working closely with the EU/Euratom institutions, partners in Member States and industry.

There have been important steps forward in addressing the challenges. This report shows significant progress in the security of supply for VVER reactors for most countries. It also shows important challenges ahead, notably in relation to diversification in conversion and enrichment services.

Building upon ESA's analysis of the market situation, this report contains a series of recommendations to support market actors to navigate the complex environment we operate in.

The new reality of security of supply also strongly affects to Agency itself. For the second year, ESA had to mobilise and concentrate its resources on crisis management. The arrival of new market actors and the emergence of new technologies means that new supply chains will be developed. In the coming years, ESA will have to be prepared to support a range of new partners, handle an increasing number of transactions and be able to analyse and report on market developments in a more dynamic way.

The Agency's success depends on the commitment and competence of its small and dedicated staff, working under high work pressures to deliver on ESA's tasks and outputs.

I would also like to pay tribute to the important contribution Agnieszka Kaźmierczak has made during the more than four years she served as ESA Director General.

I look forward to working closely with all partners – representatives of Member States, supply chain actors, the Advisory Committee and colleagues at the Commission – towards achieving ESA's objectives in the changing security of supply landscape.

Michael Hübel
Director-General of the Euratom Supply Agency

Contents

Executive summary

This comprehensive report describes the current state and future projections of the nuclear fuel market in the European Union. It emphasises the critical aspects of nuclear fuel consumption, procurement trends and strategic management. Amidst the backdrop of geopolitical tensions, particularly the Russian invasion of Ukraine, the EU is actively seeking to diversify its energy sources and reduce dependency on Russian nuclear supplies. The report also explores market dynamics, pricing trends, and the role of the Euratom Supply Agency (ESA) in ensuring a secure supply of nuclear materials. It looks at the impact of broader nuclear policy developments in the EU and innovation in the nuclear sector on security of supply.

Finally, it presents the activities and achievements of the ESA in 2023.

Market analysis and recommendations

In 2023, nuclear power accounts for approximately 23% of the EU's total electricity generation, with 103 operational reactor units. This report provides a detailed analysis of the nuclear fuel supply and demand in the EU, focusing on several aspects such as acquisition prices, fuel loading, future requirements and inventory patterns.

The EU's demand for natural uranium accounts for about 22% of global needs. Utilities have been purchasing more material than they load into reactors, a trend driven by the geopolitical tensions resulting from the Russian aggression against Ukraine. The report also highlights the increasing utilisation of secondary sources such as MOX and reprocessed uranium, projecting a significant rise in their use over the next decade.

On the supply side, EU utilities continue to diversify their sources of nuclear fuel, particularly for VVER reactors, to mitigate dependency on single suppliers and designs or reduce high-risk supplies. Nearly all countries operating Russian-designed reactors are progressing in licensing alternative fuel designs, with promising developments expected in the near future. Deliveries of natural uranium and other nuclear services increased in 2023, including deliveries from Russia, primarily for stockpiling purposes. The majority of natural uranium delivered to EU utilities came from Canada, Russia, Kazakhstan and Niger, with a notable increase in supplies from non-CIS countries and Canada.

This report also analyses the conversion and enrichment service markets, highlighting potential capacity shortages, especially in the 'global west', underscoring the importance of securing these services. It highlights notable investments in domestic capacities in the UK and the US, alongside expansions by companies such as Urenco and Orano. The report emphasises the need to invest further in maintaining a stable and reliable supply of conversion and enrichment services over the long term.

Inventory levels of nuclear materials have risen. Overall, there is sufficient coverage for future reactor reloads, although the sufficiency of these inventories varies among utilities.

Looking ahead, the nuclear fuel requirements are stable compared to previous yearly forecasts. The EU utilities are well-prepared and have contracts to cover future needs, although the situation is more nuanced for minimum contractual arrangements. The Agency observes that conversion and enrichment capacities appear largely contractually committed in the short term, potentially limiting the execution of all options in existing contracts from open market suppliers to compensate for high-risk supplies.

Price indices for nuclear fuel cycle products have risen due to market uncertainties and shifts towards more reliable sources.

The supply of medical radioisotopes remains a concern namely due to reliance on foreign supplies of their source materials, particularly from Russia.

Finally, the Agency presents a series of recommendations to ensure a secure and stable supply of nuclear materials and services in a challenging and constrained market. The challenges are due to ongoing geopolitical tensions, notably the Russian invasion of Ukraine affecting the global energy supply system, and future projections that anticipate a rise in global requirements over the next two decades, driven by national policies and the potential introduction of new technologies such as modular reactors.

Nuclear policy and market developments in the EU and worldwide

Overall, the EU's nuclear energy policy in 2023 was marked by action to enhance the safety and security of supply, reduce dependency on external energy supplies, and support the transition to a decarbonised energy system, all while navigating complex geopolitical challenges.

The report sets out how the European Commission focused on ensuring the safe and secure use of nuclear energy in the EU, emphasising nuclear safety, security and radiation protection. This was part of a broader effort to reduce dependence on Russian energy, especially in light of the geopolitical tensions arising from Russia's war against Ukraine. This action included diversifying nuclear fuel supplies for VVER-type reactors and supporting Ukraine's nuclear safety amid ongoing conflicts, particularly at the Zaporizhzhia nuclear power plant.

The EU continued to advance its decarbonisation agenda, integrating nuclear energy in the scope of several legal instruments designed to achieve the European Green Deal objectives. Notable developments included the reform of the Electricity Market Design and the adoption of the Net-Zero Industry Act, which supports the scaling up of clean technologies including small modular reactors (SMRs).

Progress was made in radioactive waste management and nuclear decommissioning. The EU supported several decommissioning activities across Member States and continued to ensure compliance with Euratom directives on nuclear safety and waste management.

In the field of emergency preparedness and response, the EU maintained robust systems for radiological emergency information exchange and radiation monitoring. The EU continued to work on strengthening nuclear safety globally, cooperating with organisations such as the IAEA and addressing safety concerns in neighbouring non-EU countries.

Post-Brexit, the EU continued cooperation with the UK in the nuclear field, maintaining engagement through various frameworks and agreements. On fusion energy, the EU supported the ITER project and other initiatives designed to develop fusion as a sustainable energy source. The construction of ITER faced delays, prompting organisational and contractual changes to meet future milestones.

Euratom safeguards were effectively implemented, ensuring that nuclear materials in the EU were used for peaceful purposes. The Commission also proposed updates to the Euratom safeguards regulation to reflect recent developments in the nuclear industry.

The EU carried out research and innovation activities under the Euratom programme, directing significant funding to enhance nuclear safety, develop SMRs, and support the safe management of radioactive waste. The EU also focused on medical applications of nuclear technology, particularly on securing the supply of medical radioisotopes and advancing cancer treatment technologies.

The report also outlines developments in the nuclear energy sector in various EU Member States, highlighting the diverse approaches and policies taken by different countries.

In terms of the global nuclear fuel market, 2023 saw some significant developments, influenced by geopolitical tensions, particularly Russia's war in Ukraine, which drove up prices across the nuclear fuel cycle. Nonetheless, there was increasing interest in the role of nuclear energy in achieving 2050 climate objectives. The COP28 conference underscored the need to accelerate the deployment of low-carbon technologies, including nuclear energy, 22 world leaders made a pledge to triple nuclear capacity by 2050.

Key developments included the Sapporo five nations' commitment to reduce reliance on Russia for nuclear fuel and to increase free-market alternatives. The US also prepared legislation to prohibit imports of certain Russian uranium products. Rising prices for uranium and related services prompted countries to consider reactivating dormant facilities and expanding capacity in western countries.

The uranium market faced geopolitical challenges and production disruptions, which pushed up prices and raised concerns about future supplies. In response, countries reported noteworthy agreements and advancements in uranium mining and conversion, including action to increase conversion capacity in the US, UK and EU.

There were also changes to enrichment services, with capacity projected to expand and new projects due to support higher assays of uranium for small modular reactors and advanced modular reactors (AMRs). Fuel fabrication is evolving with new facilities and technologies to meet specific reactor needs, while reprocessing and recycling activities continue to focus on the strategic and efficient management of nuclear materials.

Key achievements and management in 2023

In 2023, the ESA continued to refine its strategies and operations to ensure the long-term security and diversification of the EU's nuclear material supply. This was in response to existing vulnerabilities, emerging challenges and to support the EU's nuclear industry and medical radioisotope requirements amidst changing geopolitical and market conditions.

The ESA concluded a high number of supply contracts and acknowledged notifications of service supplies. It placed a strong emphasis on the origin of materials and suppliers, as well as on diversifying supply sources to enhance the security of the nuclear fuel supply chain. The Agency actively monitored and discouraged sources of supply considered to be high-risk. In cooperation with the Commission, the ESA continued to engage with utilities and industry stakeholders on the diversification process for fuel used in Russian-designed reactors within the EU. Of the five EU utilities that operate these reactors, four had signed contracts for alternative fuel supplies by the end of 2023.

With the support of its Advisory Committee, ESA continued to assess the security of supply situation and the impact of geopolitical events and market development on it. The Agency also provided expert analysis in response to geopolitical developments, particularly the impact of Russia's aggression against Ukraine. It produced analyses and statistical reports to underpin its strategic objectives.

The ESA put major emphasis on securing the supply of source materials for radioisotope production, monitoring and advising on the security of supply for medical radioisotopes, which are challenges due to dependencies on Russian production. It co-chaired the European Observatory on the Supply of Medical Radioisotopes with the Nuclear Medicine Europe (NMEU), addressing supply chain issues. During 2023, the Observatory held two plenary meetings.

The ESA also played a key role in implementing the Strategic Agenda for Medical Ionising Radiation Applications (SAMIRA). The emphasis was on action to secure source materials for radioisotope production and to scrutinise the security of supply of Highly Enriched Uranium (HEU) and High-Assay Low-Enriched Uranium (HALEU). These materials are essential for producing medical radioisotopes and fuelling research reactors. The Agency continued to implement the HEU exchange agreement with the US Department of Energy's National Nuclear Security Administration (DoE-NNSA) for supplies until users convert their research reactors to HALEU.

Throughout the year, ESA engaged with multiple stakeholders including EU authorities, utilities and international organisations, to strengthen the security of nuclear material supplies and to diversify supply sources.

On the management front, ESA achieved a high budget execution rate of 98.47%, balancing revenue and expenditure. The Agency's staff included 16 filled positions out of 17 authorised, maintaining gender balance and a diverse representation of EU nationalities. Recruitment challenges persisted due to the high cost of living in Luxembourg. In 2023, ESA received approval to proceed with the development of its core IT system, with the aim of enhancing operational efficiency and security.

Abbreviations

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
AMRs	Advanced Modular Reactors
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)
SMRs	Small Modular Reactors
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)

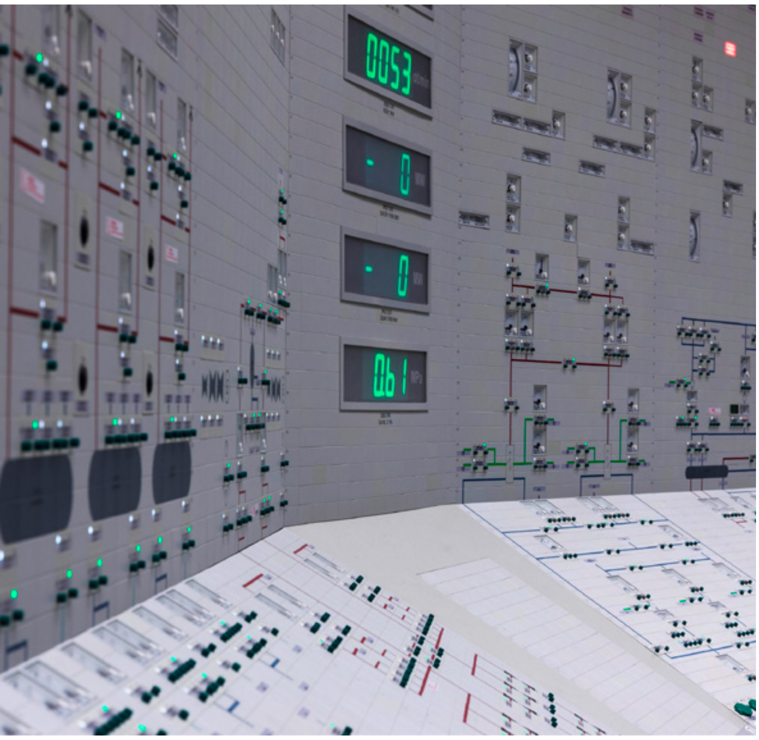
1. Nuclear fuel supply and demand in the EU

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.

In 2023, net electricity generation from the 103 reactor units operating in the 27 EU countries (EU-27) reached 587.6 TWh, [1] accounting for 22.99% of all electricity production in the EU-27.

Control room panel



©Slovenské elektrárne

1.1. Fuel loaded

In 2023, 1 771 tU of fresh fuel was loaded into commercial reactors. It was produced using 12 672 tU of natural uranium and 55 tU of reprocessed uranium as feed, enriched with 9 611 tSW.

In 2023, 1 771 tU of fresh fuel was loaded into commercial reactors.

The fuel loaded into EU reactors had an average enrichment assay of 4.24%, with 90% falling between 3.83% and 4.64%. The average tails assay was 0.20%, with over 82% falling between 0.17% and 0.24%.

MOX (mixed oxide) fuel was used in several reactors in France and the Netherlands. MOX fuel loaded into nuclear power plants in the EU contained 4 787 kg plutonium in 2023, 59% more than in 2022. The use of MOX resulted in estimated savings of 427 tU, and 300 tSW, an increase of 54% and over 52% respectively since 2022 (see Annex 5). MOX fuel is produced by mixing plutonium recovered from spent fuel and depleted uranium obtained from the enrichment process. MOX fuel increases the availability of nuclear material, reduces the need for enrichment services and increases the security of supply.

The amount of natural uranium equivalent included in fuel loaded into reactors in 2023, including natural uranium feed, reprocessed uranium, and savings from MOX fuel, totalled 13 154 tU.

The total amount of natural uranium equivalent included in fuel loaded into reactors in 2023 was 13 154 tU.

1 Source: Net electricity generation by type of fuel (Eurostat) – aggregated monthly data extracted on 23 May 2024.

MOX fuel and reprocessed uranium can be considered as domestic secondary sources that reduce the requirements for natural uranium. In 2023, they are equivalent to 3.6% of the EU's annual natural uranium requirements. 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, 7 out of 27 Member States reprocessed or plan to reprocess spent fuel, and 2 Member States did not exclude doing so.

Table 1. Natural uranium equivalent included in fuel loaded by source in 2023

Source	Quantities (tU)	% of annual requirement
Uranium originating outside the EU-27 (1)	12 672	96.4
Indigenous sources (2)	481	3.6
Total annual requirements	13 154	100

(1) Includes any small quantities of natural uranium resulting from enrichment underfeeding, re-enriched tails, and uranium of EU origin.
(2) Includes reprocessed uranium, savings from the usage of MOX fuel.

1.2. Future requirements

EU utilities have estimated their gross reactor requirements for natural uranium and enrichment services for the next 20 years, factoring in possible changes to national policies or regulatory requirements that would result in the construction of new units (the estimates only include projects already granted a construction licence), lifetime extensions, early retirement of reactors, and phasing-out or decommissioning. Plans for future new builds including new technologies (e.g. SAMRs) are therefore not included in their estimated requirements.

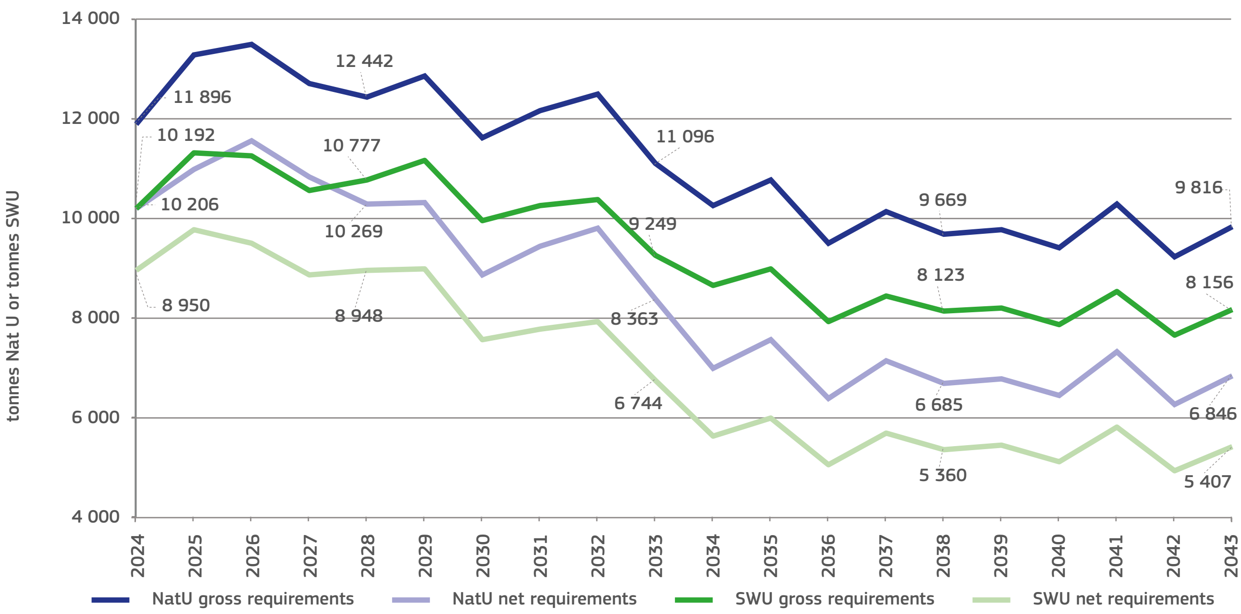
Net requirements are calculated on the basis of gross reactor requirements, minus the savings obtained from planned uranium/plutonium recycling and inventory usage.

Natural uranium – average reactor requirements		
2024-2033	12 401 tU/year (gross)	10 060 tU/year (net)
2034-2043	9 883 tU/year (gross)	6 839 tU/year (net)

Enrichment services – average reactor requirements		
2024-2033	10 509 tSW/year (gross)	8 502 tSW/year (net)
2034-2043	8 252 tSW/year (gross)	5 435 tSW/year (net)

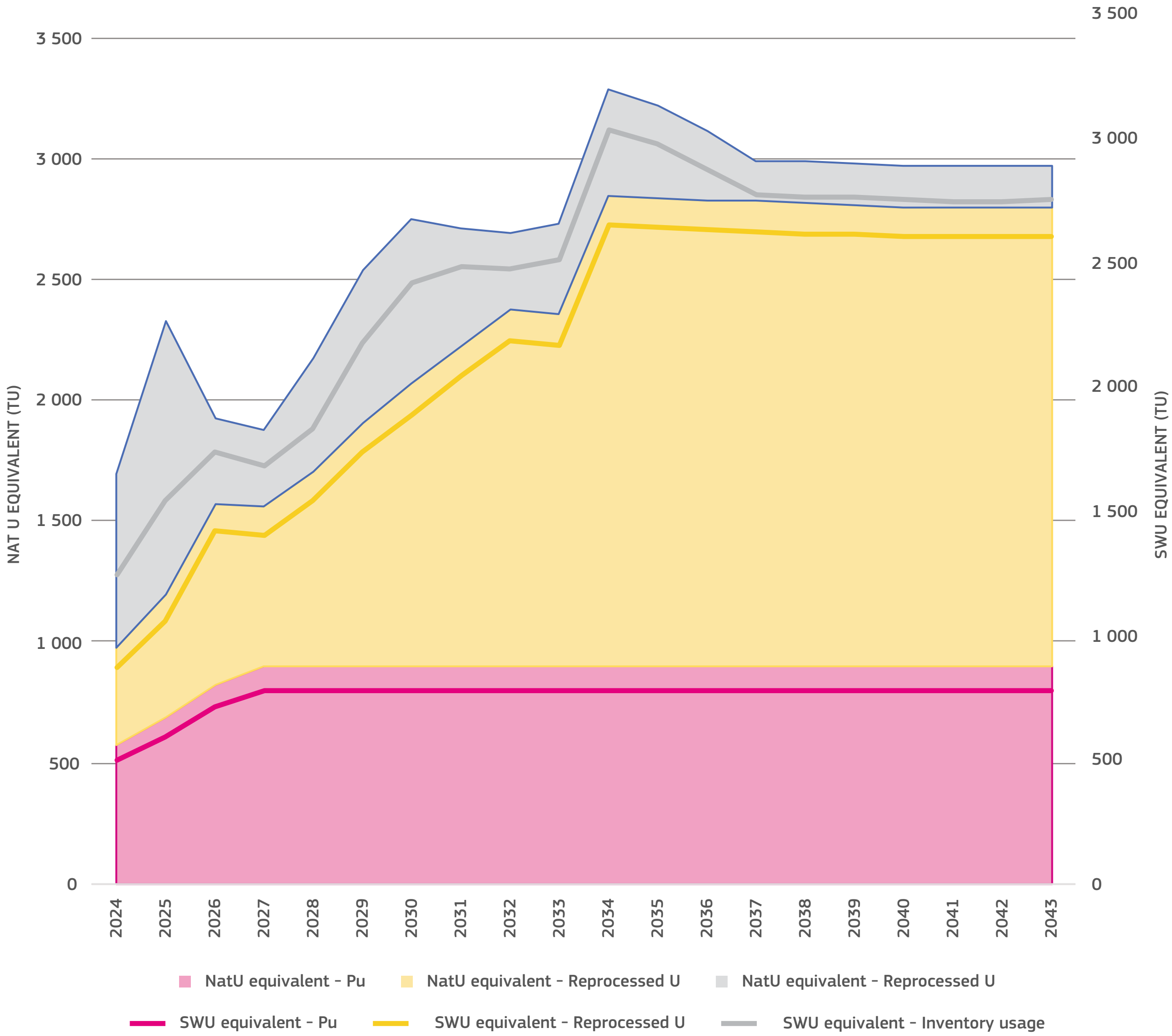
Estimates of future reactor requirements for uranium and separative work (SW), based on data supplied by all EU utilities, are shown in Figure 1 (see Annex 1 for numerical values).

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



An analysis of differences between gross and net future requirements for NatU and SWU in the next decade indicates that demand for 'secondary sources' is likely to increase (Figure 2). The trend is also influenced by fluctuating changes to the gross requirements.

Figure 2. Estimated future use of secondary sources



1.3. Supply of natural uranium

Volume of deliveries

The deliveries include those to EU utilities or their procurement organisations in 2023, excluding research reactors. Where stated, it also includes the natural uranium equivalent contained in enriched uranium purchases.

In 2023, demand for natural uranium in the EU accounted for approximately 22% of global uranium requirements. EU utilities purchased a total of 14 578 tU in 124 deliveries under multiannual and spot contracts.

As in previous years, supplies under multiannual contracts were the main source to meet demand in the EU. Deliveries of natural uranium to EU utilities under multiannual contracts accounted for 13 591 tU (of which 12 961 tU with reported prices) or 93% of total deliveries. The remaining 7% (988 tU) was purchased under spot contracts.

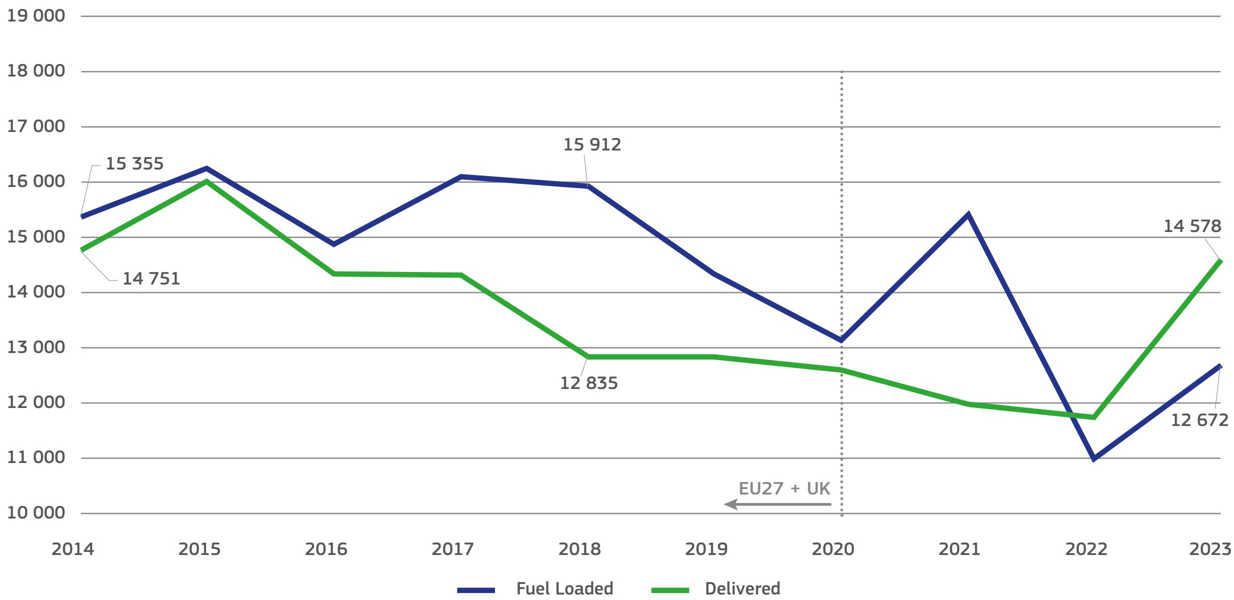
On average, the quantity of natural uranium delivered was 116 tU per delivery under multiannual contracts.

> Demand for natural uranium in the EU accounted for approximately 22% of global uranium requirements.

In 2023, similarly to 2022, EU utilities loaded less material into reactors than they bought, in contrast to the 8 years before 2022 when they bought less uranium than they loaded into reactors. Figure 3 shows the quantities of natural uranium feed contained in fuel loaded into EU reactors and natural uranium delivered to utilities (see Annex 2 for the corresponding table for 1980-2023).

> As in the previous year, in 2023 utilities bought more material than they loaded into reactors.

Figure 3. Natural uranium equivalent feed contained in fuel loaded into EU reactors and natural uranium equivalent delivered to utilities under purchasing contracts (tonnes NatU)



Average delivery prices

ESA's price calculation method converts the currency of the original contract prices, if stated differently, into euro 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 quantity delivered under each contract. Annex 3 lists the ESA historical prices and European Central Bank exchange rates. Annex 8 sets out the detailed methodology of price calculation.

1. ESA spot U_3O_8 price: the weighted average U_3O_8 price paid by EU utilities for uranium delivered under spot contracts was calculated to be:	
EUR 149.28/kgU contained in U_3O_8	A 9% increase from EUR 137.26/kgU contained in U_3O_8 in 2022
USD 60.46/lb U_3O_8	A 9% increase from USD 55.59/lb U_3O_8 in 2022

The ESA U_3O_8 spot price reflects short-term price developments on the uranium market as it is calculated from contracts for either a single delivery or for several deliveries over a maximum twelve-month period.

2. ESA multiannual U_3O_8 price: the weighted average U_3O_8 price paid by EU utilities for uranium delivered under multiannual contracts was calculated to be:	
EUR 115.79kgU contained in U_3O_8	A 14% increase from EUR 101.28/kgU in 2022
USD 48.16/lb U_3O_8	A 17% increase from USD 41.02/lb U_3O_8 in 2022

The multiannual prices paid varied widely, by approximately 67% (assuming a normal distribution) in the range of EUR 77.97 to EUR 143.65/kgU (from USD 31.58 to USD 58.18 /lb U_3O_8).

3. ESA 'MAC-3' multiannual U_3O_8 price: the weighted average U_3O_8 price paid by EU utilities under 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 103.56/kgU contained in U_3O_8	A 36% increase from EUR 76.19//kgU in 2022
USD 41.95 /lb U_3O_8	A 36% increase from USD 30.86/lb U_3O_8 in 2022

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.

Figures 3a and 3b show the ESA average price of natural uranium since 2014. The data are presented in Annex 3.

Figure 3a. Average prices of natural uranium delivered under spot and multiannual contracts, 2014-2023 (EUR/kgU)

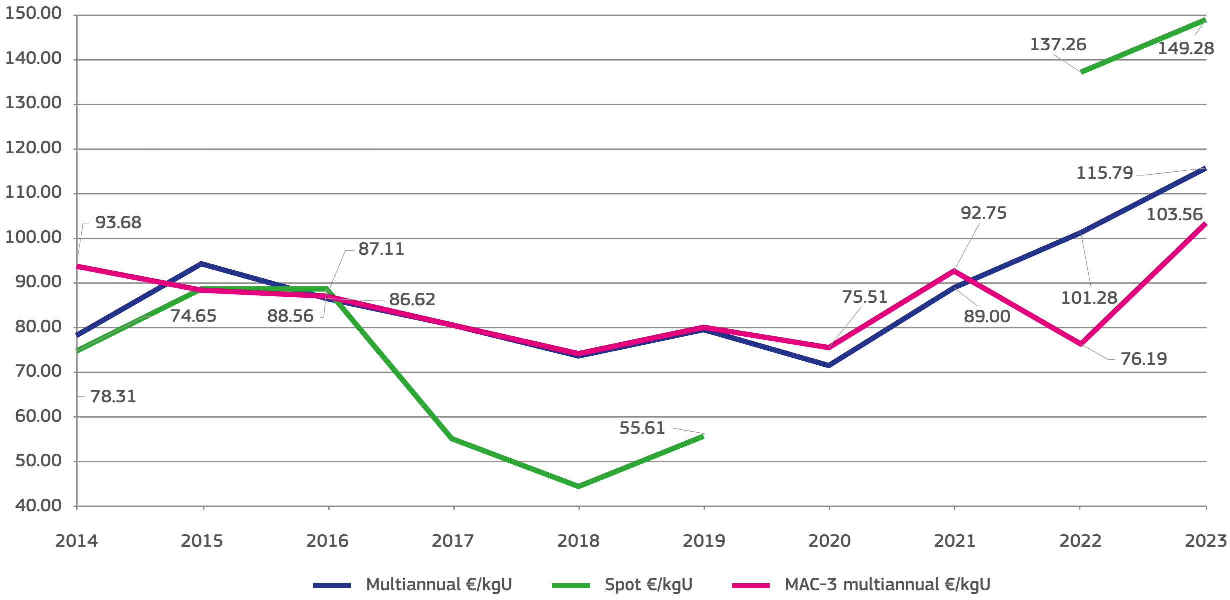
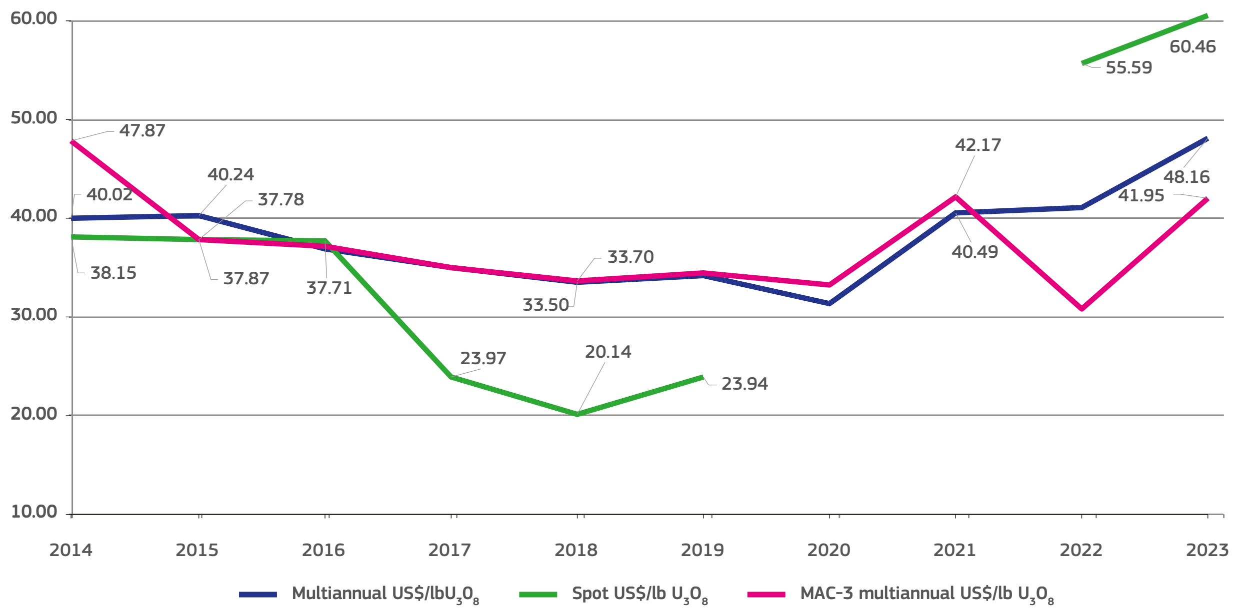


Figure 3b. Average price of natural uranium delivered under spot and multiannual contracts, 2014-2023 (USD/lb U_3O_8)



Origin of fuel supplies

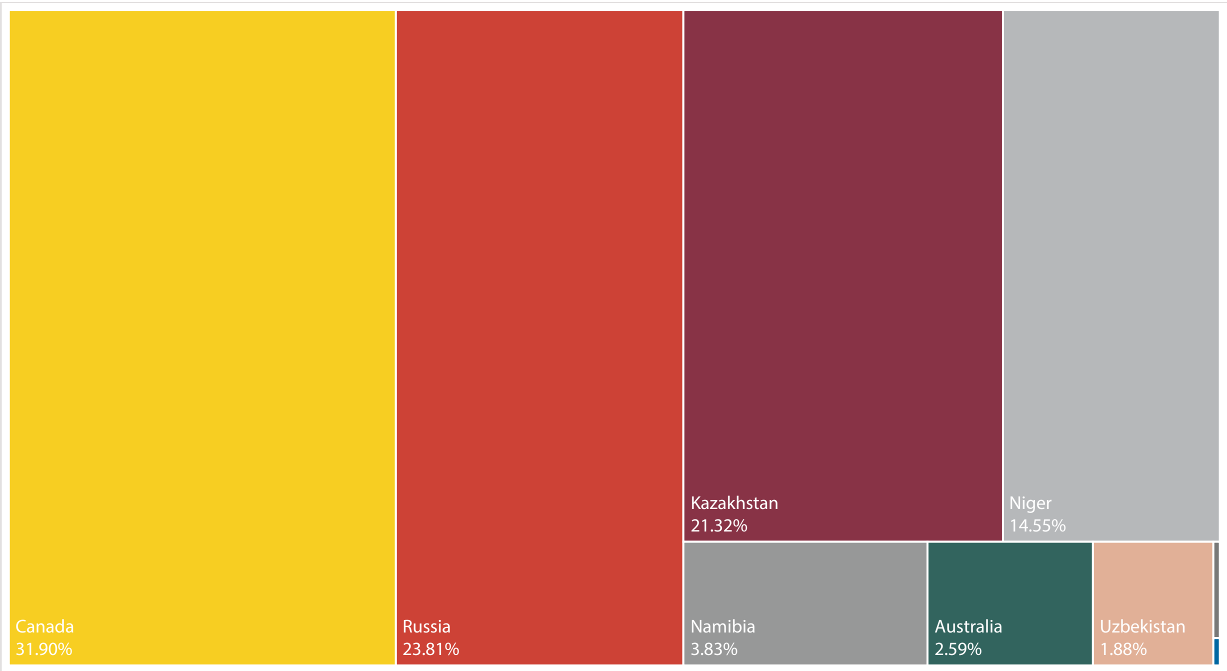
In 2023, natural uranium supplies to the EU continued to come from diverse sources. The origins of natural uranium supplied to EU utilities remained similar to 2022, though there were some changes in market share.

Table 2. Origins of uranium delivered to EU utilities in 2023 (tU)

Origin	Quantity	Share (%)	Change in quantities 2022/2023 (%)
Canada	4 801	32.94	86.26
Russia	3 419	23.45	72.69
Kazakhstan	3 061	21.00	-2.66
Niger	2 089	14.33	-29.78
South Africa and Namibia	562	3.86	114.82
Australia	372	2.55	44.56
Uzbekistan	271	1.86	-38.58
USA	4	0.03	100
EU	0	0	-100
Re-enriched tails	0	0	0
Other (1)	0	0	0
Total	14 578	100	24.35

Due to rounding, the totals may not add up.
(1) Material saved through underfeeding, mixed origin and unknown

Figure 4. Origins of uranium delivered to EU utilities in 2023 (% share)



Similarly to the previous year, the same four countries, though in different proportion, provided over 91% of all-natural uranium supplied to the EU in 2023.

Over 91% of natural uranium supplied to the EU came from four producing countries.

Natural uranium produced in Commonwealth of Independent States (CIS) countries accounted for 46.30% of all-natural uranium delivered to EU utilities. CIS deliveries amounted to 6 750 tU, which is 21.3% more by weight than the year before. Natural uranium originating in non-CIS countries accounted for 7 828 tU, a climb of almost 29% compared with the previous year.

In contrast to previous years, deliveries of uranium from Africa decreased to 2 651 tU, i.e. down by 18.09%.

Figure 5. Origins of uranium delivered to EU utilities in 2023 by geographical regions (tU)

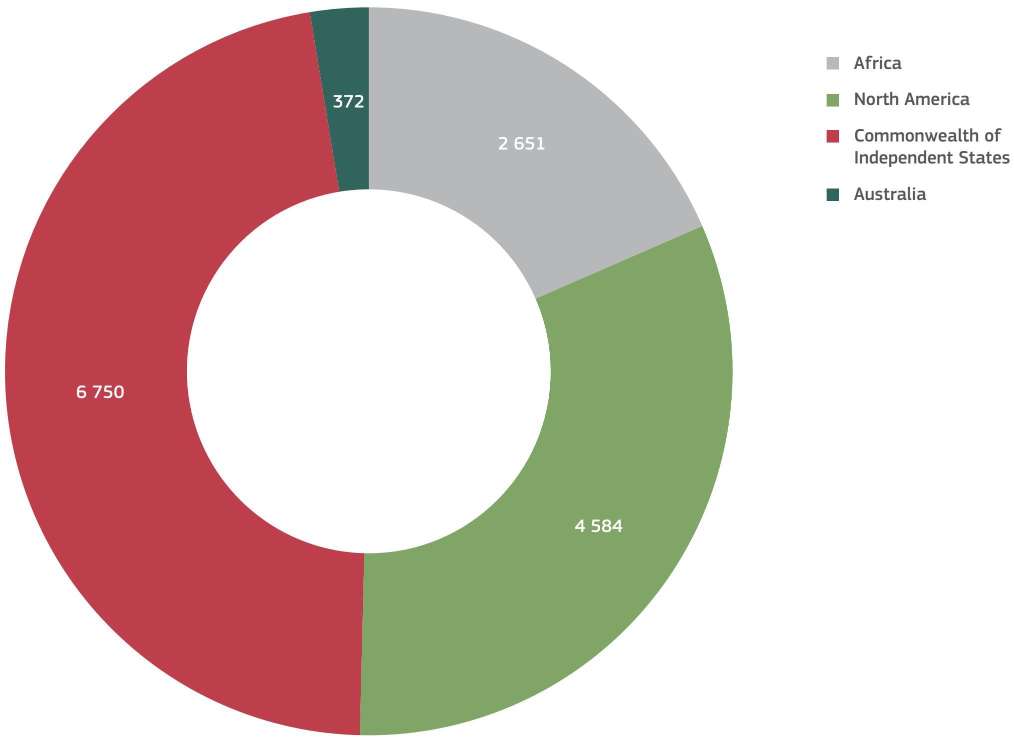
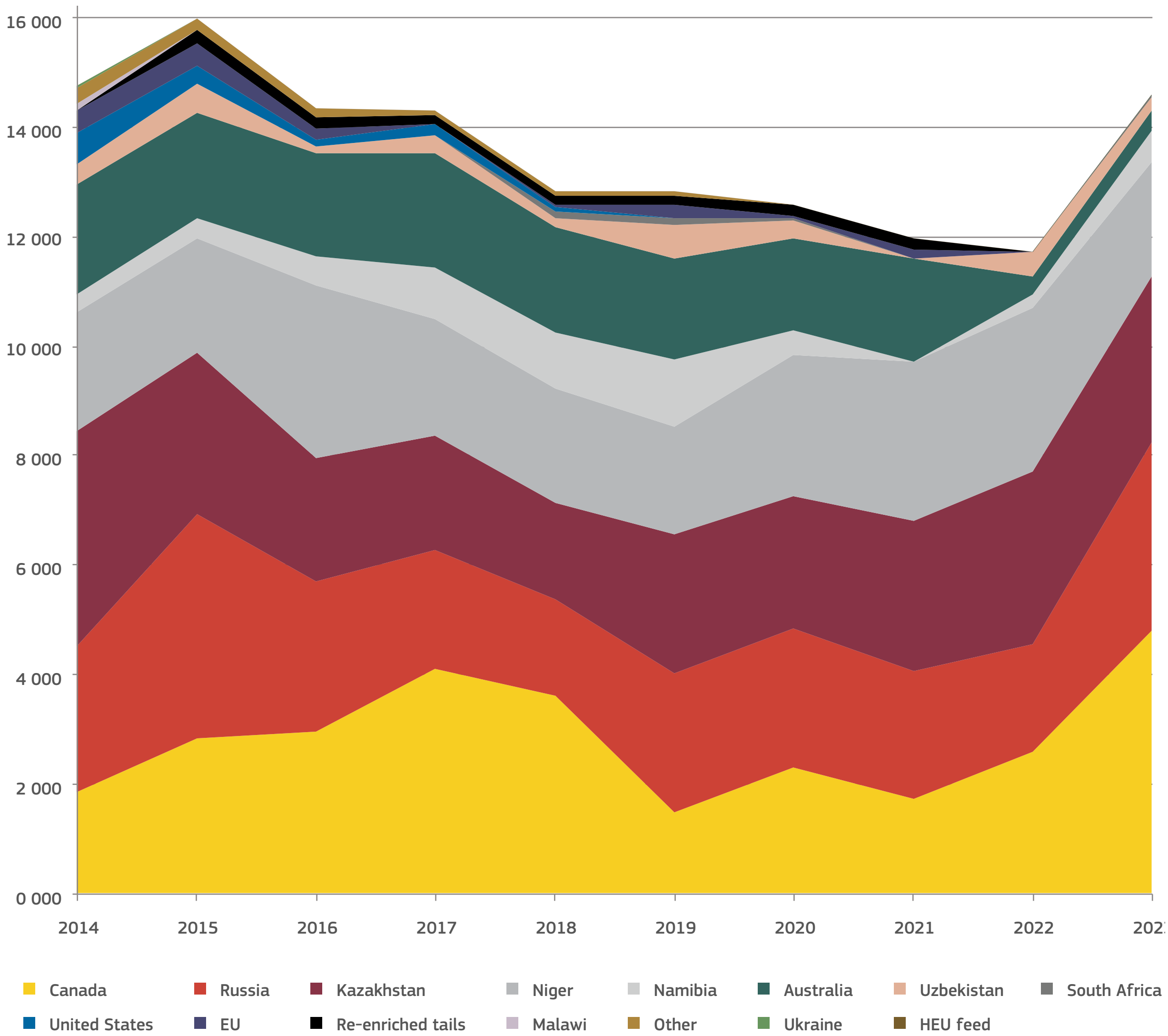


Figure 6. Purchases of natural uranium by EU utilities, by origin, 2014-2023 (tU)



Conversion services

Under separate conversion contracts, 8 091 tU were converted, accounting for 61% of all service deliveries to EU utilities. The remaining 39%, or 5 272 tU, were delivered under other types of contract (purchases of natural UF_6, EUP, bundled contracts for fuel assemblies).

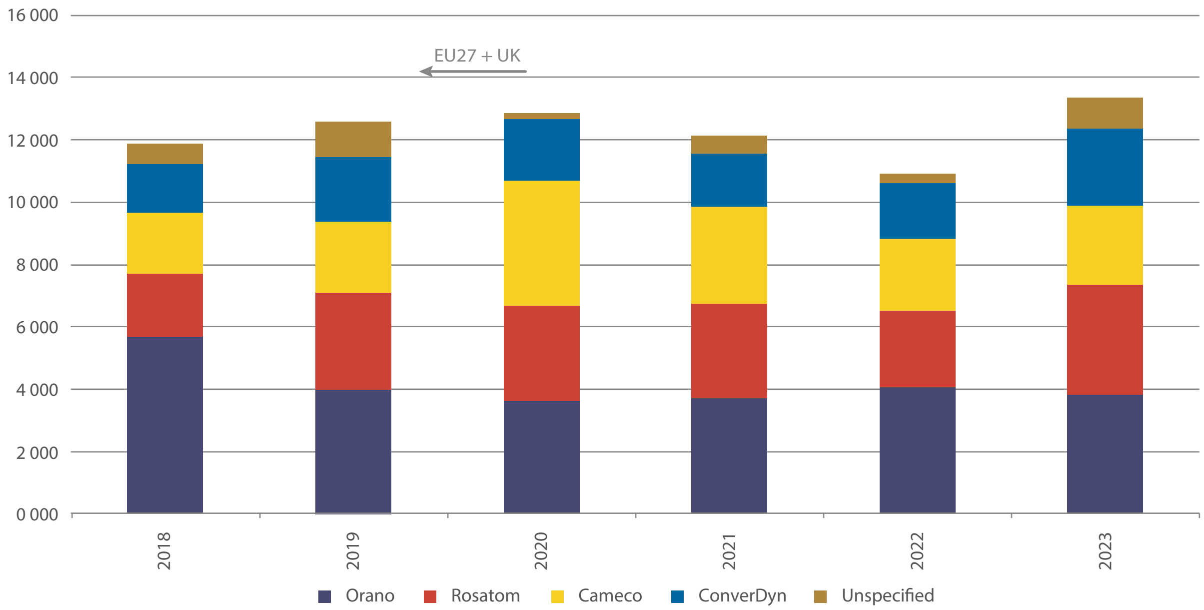
Conversion service deliveries to EU utilities were 22% higher than in 2022.

Table 3. Provision of conversion services to EU utilities

Converter	Quantity in 2023 (tU)	Share in 2023 (%)	Quantity in 2022 (tU)	Share in 2022 (%)	Change in quantities 2022/2023 (%)
Orano (EU)	3 834	28.69	4 083	37.34	-6.09
Rosatom (Russia)	3 543	26.51	2 444	22.35	44.97
Cameco (Canada)	2 525	18.90	2 314	21.16	9.12
ConverDyn (US)	2 448	18.32	1 782	16.30	37.32
Unspecified	1 013	7.58	311	2.84	226.03
Total	**13 364**	**100**	**10 934**	**100**	**22.22**

Due to rounding, the totals may not add up.

Figure 7. Supply of conversion services to EU utilities by provider, 2018-2023 (tU)



1.4. Special fissile material

Enrichment service deliveries to EU utilities in 2023 were 12% higher than in 2022.

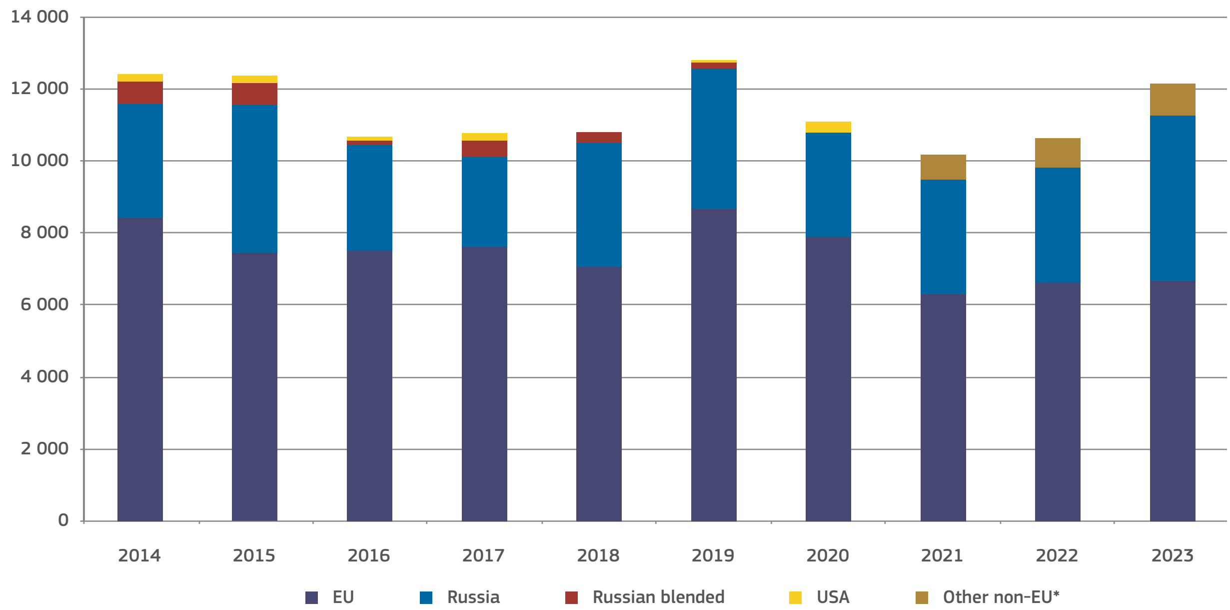
Deliveries of low-enriched uranium

In 2023, enrichment service deliveries to EU utilities were 12% higher than in 2022, with nuclear power plant operators opting for an average enrichment assay of 4.26% and an average tails assay of 0.19%.

Table 4. Origin of enrichment services to EU utilities

Enrichment origin	EUP tU 2023	Uranium feed 2023 (tU)	Quantities in 2023 (tSW)	SW share in 2023 (%)	Quantities in 2022 (tSW)	SW share in 2022 (%)
EU	1 029	7 899	6 728	54.88	6 678	62.23
Russia	649	5 370	4 647	37.90	3 239	30.18
Other *	113	937	885	7.22	815	7.59
TOTAL	1 791	14 205	12 260	100	10 732	100

Figure 8. Supply of enrichment to EU utilities by provider, 2014-2023 (tSW)

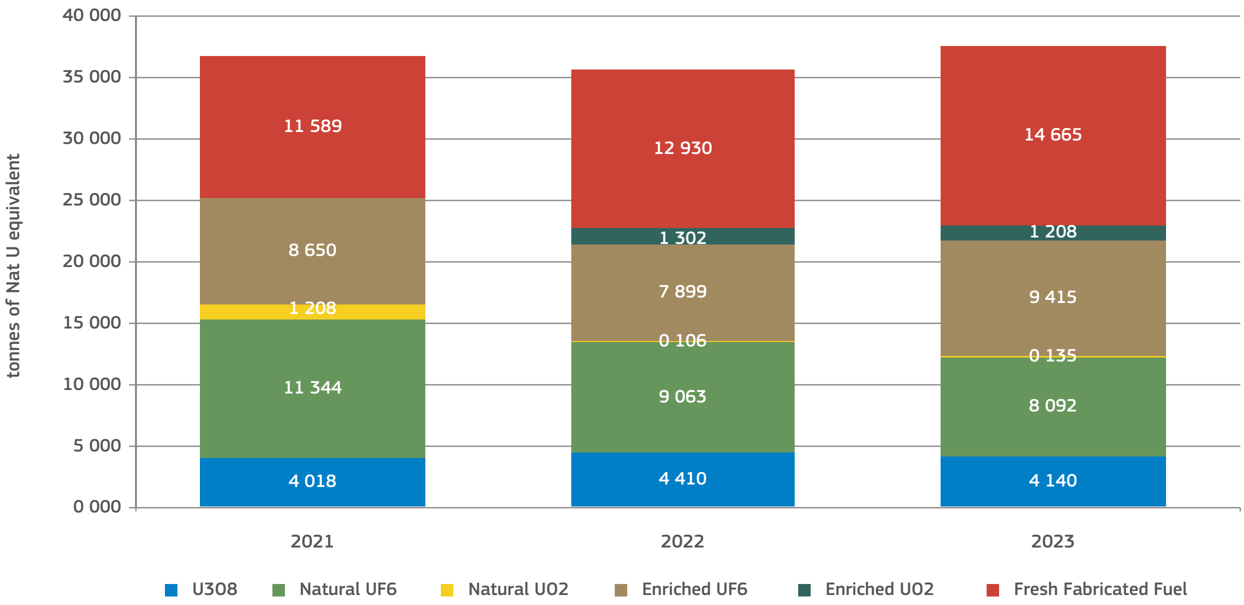


**Other non-EU, starting from 2021.*

1.5. Inventories

At the end of 2023, the natural uranium equivalent in inventories owned by EU utilities totalled 37 655 tU. The inventories comprised uranium at different stages of the nuclear fuel cycle (natural uranium, in-process for conversion, enrichment, fuel fabrication and fresh fuel), stored at EU or other nuclear facilities.

Figure 9. Total natural uranium equivalent inventories owned by EU utilities at the end of the year, by chemical form, 2021-2023 (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 (12 401 tU per year), uranium inventories are sufficient to fuel EU utilities' nuclear power reactors for three reloads on average. The average conceals that there is 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 three reloads on average.

A further analysis of EU utilities inventories shows that most are located in the EU. However, some are located outside the EU and a small fraction for future delivery is stored at unknown locations.

1.6. Future contractual coverage rate

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. Figures 10 and 12 show the maximum and minimum contractual coverage rate for natural uranium and for SWUs respectively, and Figure 11 shows the maximum and minimum contractual coverage rate for conversion services for EU utilities.

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

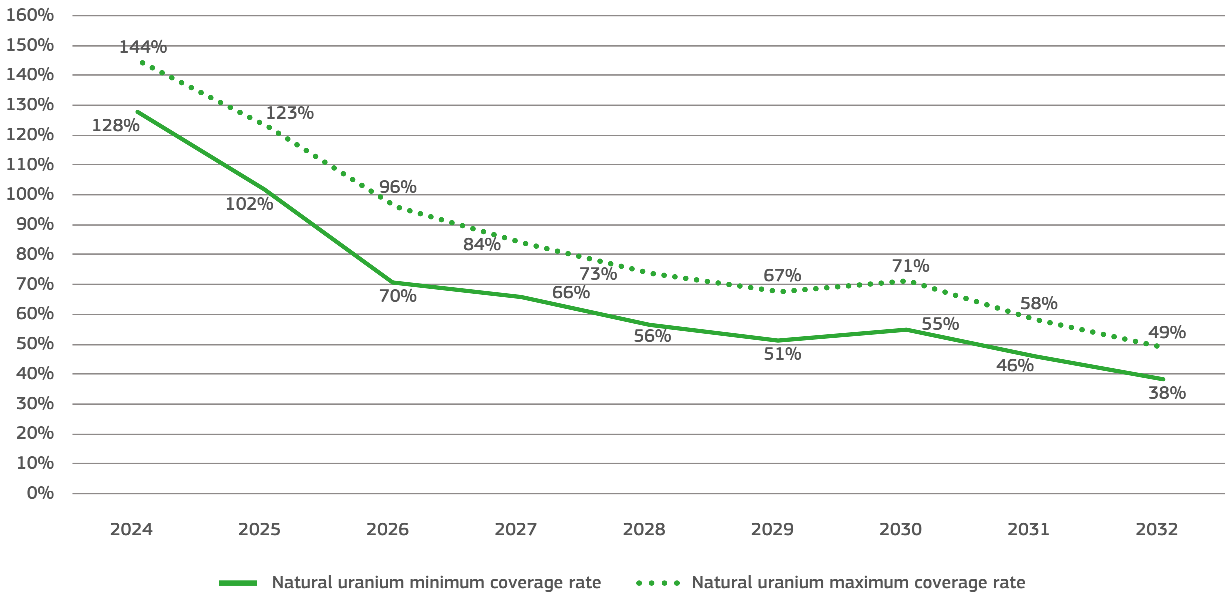
For net reactor requirements (the denominator), a distinction is made between demand for natural uranium and demand for enrichment services. Average net reactor requirements for 2024-2032 are estimated at 10 060 tU and 8 502 SW per year (see table in Annex 1). ESA assumes the same quantity of requirements 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.

A quantitative analysis shows that EU utilities are well covered under existing contracts with EU and third-country suppliers for natural uranium, conversion and enrichment services. However, when looking at minimum contractual arrangements, the situation is different.

The supply of natural uranium is well secured until 2025. From mid-2027, the supply drops to below 80% of requirements then to 67% in 2029. It decreases further in the following years to 49% in the last year of analysis in 2032.

The uranium minimum contractual coverage rate follows a similar pattern. It tapers down to reach 38% in 2032.

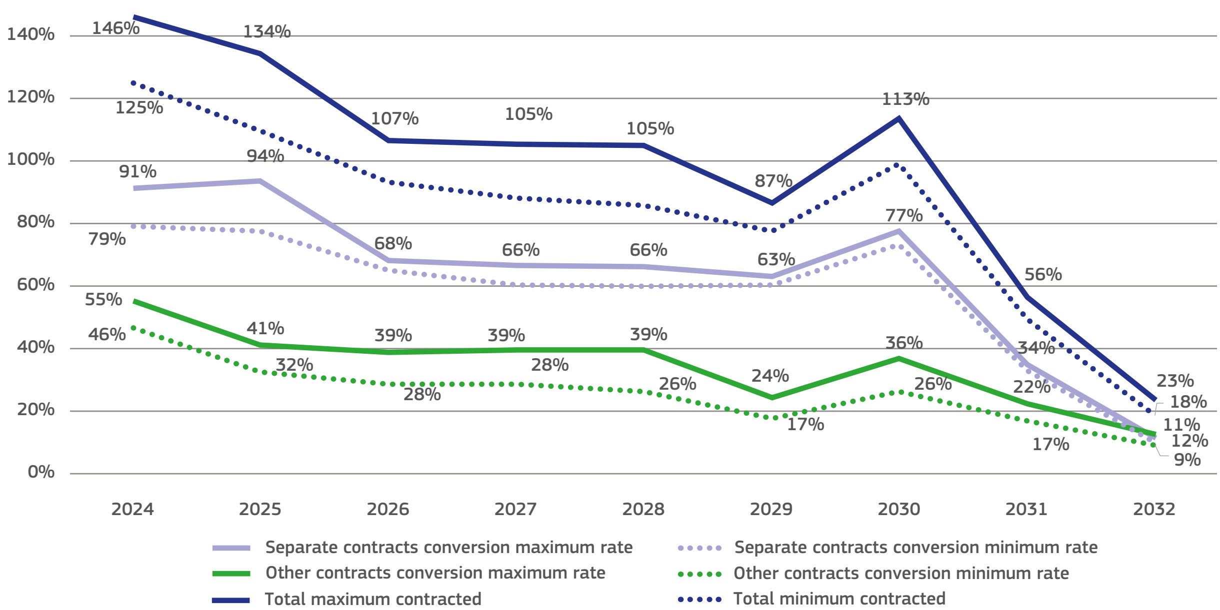
Figure 10. Coverage rate for natural uranium, 2024-2032 (%)



A quantitative analysis of conversion services shows that EU utilities' net reactor requirements are well covered under existing contracts, with maximum conversion services coverage rates above 100% until 2030. This drops sharply to 56% in 2031, and then reaches 23% of requirements in 2032, the last year in the analysis.

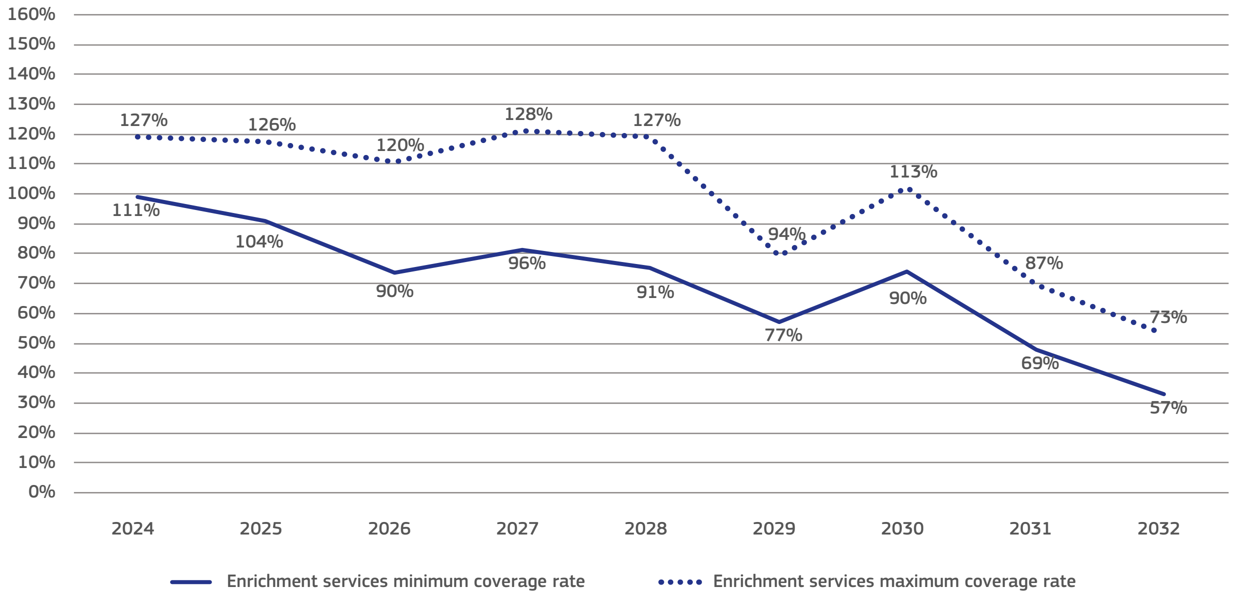
However, the situation is somewhat different for the minimum contractual coverage rate. The minimum contracted supply of conversion services will cover between 125% and 93% of requirements in the first 3 years of analysis. It then fluctuates between 93% and 77% from 2026 to 2029, and then drops again to a very low level of 18% by 2032.

Figure 11. Coverage rate for conversion services, 2024-2032 (%)



The supply of enrichment services is well secured over the whole period of analysis. The maximum coverage rate varies between 127% and 113% up to 2030, falling only to 94% in 2029 ending at 73% in 2032. The minimum contractual coverage rate oscillates from 111% to 91% in 2024-2028, then drops to 77% in 2029 to reach 57% in 2032.

Figure 12. Coverage rate for enrichment services, 2024-2032 (%)



2. Security of supply

The regular and uninterrupted supply of fuels, both for power and non-power applications of nuclear energy, is of paramount importance for the European Union. Nuclear power plants generate almost a quarter of all electricity in the EU, and this share is over 40% in several Member States (France, Slovakia, Hungary and Bulgaria). In addition, millions of Europeans rely on the diagnostic and therapeutic uses of ionising radiation each year. Disruptions in supply would therefore have severe consequences for people, hospitals and industry.

Since 2022, the functioning of the nuclear market has been profoundly affected by major geopolitical events in Europe. Russia's invasion of Ukraine has significantly impacted the European Union's energy security. It severely disrupted the global supply system for all sources of energy and intensified concerns about the EU's reliance on Russian resources and supplies. The conflict has also raised concerns about the EU's security of supply for nuclear materials and services and has aggravated dependence issues.

In response, the EU is actively exploring alternative energy sources and further diversifying its energy imports to reduce its dependence on Russia for energy and nuclear fuel supplies, so to strengthen its long-term energy security. The Euratom Supply Agency (ESA) is supporting this process.

> According to the measures put forward in the REPowerEU plan of 2022, diversification is particularly important for Member States that are dependent on Russia for nuclear fuel for their reactors, either for power generation or non-power uses.

According to the measures put forward in the REPowerEU plan [2] of 2022, diversification is particularly important for Member States that are dependent on Russia for nuclear fuel for their reactors, either for power generation or non-power uses. The plan underlined the need to work together with global partners to secure alternative sources of uranium and to boost the conversion, enrichment and fuel fabrication capacities.

> There is a renewed interest in nuclear energy as a low-carbon alternative to fossil fuels, both in the European Union and around the world.

In addition to the increased focus on energy security, there is a renewed interest in nuclear energy as a low-carbon alternative to fossil fuels, both in the European Union and around the world. Nuclear energy is seen as complementary to renewable energy to both achieve the climate objectives and to strengthen energy security amid geopolitical tensions and the need to reduce dependence on fossil fuel imports from unstable or unreliable sources. Emerging technologies, such as small and advanced modular reactors (SAMRs), are making some progress in research and development and could play a role in integrated energy systems.

In the light of these developments, there are obvious challenges for the security of supply of nuclear material and services.

As in other energy sectors, nuclear industry and power operators should aim to guarantee regular and sufficient supplies, irrespective of the structure of the market for supplies. As outlined in previous ESA reports, various measures are available to reduce the risk of interruptions in supply or to limit their effects. These include diversified and unbundled long-term contracts, keeping inventories at the right level also for production and finding alternative transport routes and means. Since the market conditions are not sufficiently stable and the current geopolitical situation could potentially have a severe impact on the supply chain or logistics, additional mitigation measures are required to ensure power plants can operate in the long term.

Ensuring secure supplies, from ore to nuclear fuel, is a strategic objective of the Agency across its activities. This includes monitoring developments in the nuclear fuel market and in related technological fields to identify market trends that could affect the security of the EU's supply of nuclear materials and services.

2 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 18.05.2022 – COM(2022) 230 final.

This chapter presents the Agency's analysis and recommendations based on data provided by EU utilities and information from monitoring the EU nuclear fuel market and global developments.

2.1. Analysis of market trends

The Agency has compiled comprehensive statistics on the situation of the EU nuclear market in Chapter 1. This section analyses market trends and developments and their impact on the security of supply.

> Russia's invasion of Ukraine has created a new context for the EU's security of supply for nuclear materials and services.

Russia's invasion of Ukraine has created a new context for the EU's security of supply for nuclear materials and services. In response to the invasion, the EU and like-minded countries have adopted far-reaching restrictive measures in a range of areas, targeting organisations, individuals and certain activities, but also affecting transport and trade. So far, nuclear fuel and services have been exempted from direct restrictions. Meanwhile, various challenges have emerged affecting transport routes, in particular nuclear fuel logistics, and connected financial transactions as a result of measures in areas other than nuclear and/or from third countries.

The global situation is also evolving. For example, the US decided to move towards a ban on uranium imports from Russia. There are concerns that markets could further tighten and become more limited, given the dependencies in particular in conversion and enrichment capacities, and in the supply of fuel to operate Russian-designed reactors.

> Since 2022, almost all EU operators of VVER nuclear reactors have contractually diversified their nuclear fuel supply.

Since 2022, almost all EU operators of VVER nuclear reactors have contractually diversified their nuclear fuel supply. [3] Some are already well advanced in the licensing process to meet nuclear safety requirements. Some utilities operating VVER reactors have been building fresh fuel stocks to cover the period until alternative fuels – including related plant adaptations – are completed and licensed. Other nuclear operators purchased higher quantities of enriched products as part of their security of supply measures.

This meant that deliveries of natural uranium and services at all stages of the nuclear fuel cycle increased in 2023. This includes deliveries from Russia, driven by VVER fuel stockpiling, where contracts are generally bundled with the supply of nuclear fuel-cycle services and material. At this stage, the increase should not be read as an indication of a trend or heightened EU dependency on Russian supplies.

Inventories

The ESA has long recommended that EU utilities maintain sufficient strategic inventories and use market opportunities to increase their stocks, depending on their individual circumstances.

> In 2023 the overall EU inventory level increased by 5.45%.

In contrast to the previous eight years, in 2023 the overall EU inventory level increased by 5.45%. Already in 2022, several utilities increased their stocks to manage the unstable market conditions following Russia's aggression against Ukraine. EU fresh fuel stocks grew by 15% over the course of 2023. In addition, there was a 13% increase in enriched uranium stocks held by utilities that – as part of security of supply measures – purchased higher quantities than required given

3 As of June 2024, Hungary had not yet contractually committed to an alternative supplier.

the uncertainty of available open-market conversion and enrichment capacity in the coming years.

All utilities have nuclear material in their inventory to cover between one to more than three reloads each, with the vast majority covered for more than two reloads. More than 60% of the inventory is kept in the form of enriched uranium or fresh fuel.

Whether the inventory level is sufficient for a particular utility depends on its profile and risk factors. The ESA considers that most utilities' inventories remain at a healthy level.

Demand

> In 2023, 10% more fuel (1 771 tU) was loaded into commercial reactors than in the previous year.

In 2023, 10% more fuel (1 771 tU) was loaded into commercial reactors than in the previous year. Natural uranium contained in the fuel loaded into reactors in 2023 totalled 12 672 tU.

14 578 tU of uranium was delivered to the EU. Utilities bought approximately 15% more material than they loaded into reactors. This contrasted with the eight consecutive years prior to Russia's aggression against Ukraine.

Estimates of future reactor requirements for uranium and enrichment services in the next decade, compared with the previous year's estimate, remained substantially unchanged.

In comparison to 2022, the analysis also shows a 44% increase (by 147 tU) of domestic sources (MOX fuel and reprocessed uranium). This is expected to continue to rise and to stabilise at around 2 800 tU after 2034.

Supply diversification

The main objectives for the long-term security of supply include diversifying supply sources for EU utilities, preventing over-reliance on a single non-EU design or supplier, and maintaining the competitiveness of EU industry throughout the fuel cycle. The ESA has long advised utilities to secure their current and future needs by concluding multi-year contracts with a range of suppliers.

Origin

In line with the ESA's recommendation, deliveries of natural uranium to the EU under multiannual contracts accounted for 93% of total deliveries in 2023. The remaining 7% were spot contracts.

Overall, deliveries of natural uranium to EU utilities remain diversified. As for the mining origin, the same four big producing countries as 2022 (Canada, Russia, Kazakhstan and Niger) provided more than 91% of the natural uranium delivered to the EU, with the relative shares of individual countries varying.

> The same four big producing countries as 2022 (Canada, Russia, Kazakhstan and Niger) provided more than 91% of the natural uranium delivered to the EU.

Nevertheless, there is a concentration of supply originated in the CIS region, including a significant part from Russia. Russian supply to EU utilities in 2023 increased by 72% driven up by the deliveries of VVER fuel for stockpiling.

At the same time, non-Russian supplies also continued to grow. In particular, Canada recorded an increase of more than 2 200 tU after a rise of more than 800 tU in 2022. Despite the volume of deliveries from Africa decreasing, there is noteworthy growth from countries other than Niger, particularly from Namibia.

A number of utilities buy their natural uranium from only one supplier.

Conversion

Orano (the Philippe Coste facility) remains the largest supplier of conversion services (aggregated stand-alone and 'bundled' with other services), although its deliveries fell by 6%. At the same time, Cameco supplies increased by around the same volume. There was a significant increase in conversion services provided by Converdyn (by some 37%).

> Due to the effect of VVER fresh fuel stockpiling, Russian supplies were higher than in 2022.

Like in the other segments of the fuel cycle, due to the effect of VVER fresh fuel stockpiling, Russian supplies were higher than in 2022 (almost 45%). Consistently, the proportion of conversion provided as part of contracts ‘bundled’ with other services (fresh fuel fabrication, EUP) increased from one third in 2022 to 39% as, for most ‘bundled’ VVER contracts, conversion services are carried out in Russia.

Enrichment

In 2023, enrichment service deliveries to EU utilities were 12% higher than in 2022. As for sources of supply of enriched uranium to EU utilities, 55% of enrichment services originated in the EU. The remaining share was provided by non-EU sources. Deliveries of separative work from Russia to EU utilities accounted for 38% of the total (30% in 2022) and the volume delivered to western-type reactor operators remained at the same level as 2022. Volumes delivered from EU enrichers and other sources were marginally higher than in 2022 (1.1% up).

> In 2023, enrichment service deliveries to EU utilities were 12% higher than in 2022.

As for sources of supply of enriched uranium to EU utilities, 55% of enrichment services originated in the EU. The remaining share was provided by non-EU sources. Deliveries of separative work from Russia to EU utilities accounted for 38% of the total (30% in 2022) and the volume delivered to western-type reactor operators remained at the same level as 2022. Volumes delivered from EU enrichers and other sources were marginally higher than in 2022 (1.1% up).

On average, utilities opted for a 4.26% enrichment assay, marginally higher than in 2022 (4.22%). The contracted tails assay remained identical and amounted to 0.19%.

Fuel

Most EU utilities have access to at least two alternative fuel fabricators. In contrast to the situation elsewhere in the EU, dependence on a single design and supplier of fuel for water-water energy reactors (VVER) remains a significant vulnerability for the security of supply. In 2023, the Commission awarded a grant of EUR 10 million to the ‘Accelerated Program for Implementation of secure VVER fuel Supply’ (APIS) [4] to carry out the necessary safety analyses and tests and put in place procedures needed to license alternative non-Russian fuel design for VVER reactors in the EU and Ukraine. The Agency notes the efforts by operators and producers to design, have licensed and create fabrication capacity for alternative fuel design for VVER reactors. With the exception of Hungary, which has not finalised the contractual procedure, countries operating VVER reactors are well advanced on the path to fuel diversification. [5] However, changing to new fuel is a multi-year project that requires national regulatory approval. For VVER-1000s, [6] the process by the respective national nuclear safety authorities to license alternative fuel design has been underway for several years, with the first concrete outcomes expected in 2024. [7]

> Dependence on a single design and supplier of fuel for water-water energy reactors (VVER) remains a significant vulnerability for the security of supply.

Fuel rack

©*Slovenské elektrárne*

4 Accelerated Program for Implementation of secure VVER fuel Supply (APIS) project description: https://apis-project.eu/
5 ESA 3rd & 4th quarter 2023 Uranium market report, see: https://euratom-supply.ec.europa.eu/index_en
6 VVER-1000 units are operational in Bulgaria and Czechia.
7 In April 2024, the Bulgarian Agency for Nuclear Regulation (ANR) issued a permit to Unit 5 of the Bulgaria’s Kozloduy nuclear power station to start using Westinghouse-made nuclear fuel RWFA for VVER-1000. On 29 May 2024, the Westinghouse fuel was loaded.

Work continues to develop alternative fuel designs for VVER-440 [8] reactors and to cooperate with suppliers other than the original suppliers. In some cases, licensing with the respective safety national authorities has started and dummy fuel assembly tested. In the meantime, utilities have increased their fuel stocks to fill the gap until alternative fuel is available and licensed. This has led to a further increase in the uranium, conversion and enrichment services delivered from Russia.

For power plants using other fuel designs, the short-term risk of dependency from unreliable suppliers appears less significant, to the extent that deliveries from reliable sources have covered most of the needs, both in materials and enrichment services.

EU and global fuel cycle market (conversion and enrichment)

In 2023, ESA conducted an analysis of the conversion and enrichment markets, covering information from EU-based enrichment and conversion plants, service providers, fuel producers, utilities, World Nuclear Association global uranium demand scenarios and other open-source information. The analysis highlighted potential capacity shortages in both conversion and enrichment sectors, especially in the 'global west', and the importance of contractually secure supplies and services for Euratom Member States.

> The analysis highlighted potential capacity shortages in both conversion and enrichment sectors, especially in the 'global west'.

Since then, several developments have occurred that affect the market.

The UK and United States have taken significant action to invest in their domestic capacity. The US has moved towards banning Russian supplies. Open-market converters have been ramping up capacity, the Metropolis plant has resumed production and Westinghouse received a grant from the UK government to explore the development of Uranium Conversion Services at Springfields. On the other stage of the nuclear fuel cycle, Urenco and Orano have announced enrichment capacity expansions in US and Europe.

These developments are leading to a shift in the balance of global supply and demand for conversion and enrichment services as they increase open-market production capacity and help countries move away from unreliable supplies.

Nonetheless, the future perspectives of the nuclear market remain uncertain. The long-term western fuel-cycle capacity gap remains. It may even widen as demand is likely to rise due to renewed interest in nuclear production as a means to strengthen energy security and contribute to achieving the climate objectives.

Further investment in new capacity will be crucial to ensure a stable and reliable supply of conversion and enrichment services in the future. For new investments, the nuclear industry requires a stable and predictable market environment for the significant capital expenditure to be viable. Historically, Russia has gained market share by offering competitive prices, which has led to concerns among industry players about whether new investments in plant extensions would be profitable in the long term. To address these concerns, there is a need for long-term contracts and clear political commitments that provide assurances to investors.

Looking at the short-term (at least up to 4 years) the Agency notes that conversion and enrichment capacity appears largely contractually committed. Fleet requirements from Euratom Member States for the coming years are well covered by contractually secured supplies and services. Nevertheless, it may not be possible to execute all options in existing contracts from open market suppliers to make up for high-risk supplies.

The question of capacity on the 'western' market of services for reprocessed uranium, in particular conversion, requires attention to avoid undermining the advantages offered by reprocessed uranium in terms of energy independence, environmental impacts and economics.

Prices

As a result of the market uncertainty and the considerable shift to reliable source of supply, prices of nuclear fuel cycle products continued to rise in 2023.

> Prices of nuclear fuel cycle products continued to rise in 2023.

8 VVER-440 units are operational in Czechia, Finland, Hungary and Slovakia.

The ESA U_3O_8 price indices were 9%, 14% and 36% higher than 2022 respectively. At the same time, price indices of uranium originating in CIS countries were 28%, 26% and 25% lower than the price for uranium of non-CIS origin.

On the global market, the average spot price of UxC natural uranium was 26% up and amounted to USD 62.13 per lb U_3O_8. The UxC average long-term natural uranium price was 20% up and amounted to USD 57.83 per lb U_3O_8.

Compared to late 2022, the average price of conversion services was USD 40/KgU in both the EU and North American markets, reaching record highs. This is 30% above the previous year average price.

The average price of UxC enrichment rose to USD 137.42 / kg SWU, a 55% increase year to year.

Long-term prices also rose in 2023. Compared to 2022, the average price of UxC conversion rose by over 20% to reach almost 30 USD per KgU. The average price of UxC enrichment rose to USD 144.75 per kgSWU, a 25% increase.

Medical radioisotopes

The ESA notes that foreign dependencies remain in several steps of the medical radioisotope supply chain. This could endanger the EU's strong position in producing medical radioisotopes and the development and application of nuclear medicine products and procedures.

Foreign dependencies remain in several steps of the medical radioisotope supply chain.

This could endanger the EU's strong position in producing medical radioisotopes and the development and application of nuclear medicine products and procedures.

One of the key conditions for the uninterrupted supply of medical radioisotopes is the availability of nuclear materials for the production of irradiation targets and fuel for research reactors. High-assay low-enriched uranium (HALEU) is currently not produced in the EU and can only be imported from the US or Russia. Current US production is based on down-blending of inventories estimated to last until 2035-2040, depending on the rate of use of the existing stockpile.

Interest in HALEU has grown over recent years because of its use to fuel certain advanced reactors.

Interest in HALEU has grown over recent years because of its use to fuel certain advanced reactors. The US DoE is pursuing various pathways to produce HALEU through its HALEU Availability Program, authorised by the Energy Act of 2020 to meet the need for the material. The Inflation Reduction Act, signed into law in 2022, also included a USD 700 million support package.

Similarly, the UK government announced it will invest GBP 300 million in launching a HALEU programme.

In terms of securing EU HALEU supply for medical isotopes, the options identified by the Agency's working group for achieving different levels of security of HALEU supply for the EU, listed in the 2022 report, [9] remain on the table.

The ESA is involved in the Commission's work to develop options for metallic HALEU supply in the context of the European Radioisotopes Valley Initiative (ERVI) under the SAMIRA action plan. In addition, a Euratom research project, 'Preparatory phase for a European production capability to secure a supply of HALEU fuel', [10] has been launched and aims to develop cooperation between stakeholders to reach the level of maturity required to potentially enable construction work to start EU production capability. These initiatives are taken forward in close cooperation with Member States, industry and users. The EU still has technical know-how on how to convert uranium to metal, but this may soon be lost as the metallisation process on an industrial scale has been suspended in the EU for over 10 years.

The ESA also notes as a point of concern the dependence on Russia for the enrichment of stable isotopes needed to produce several new medical radioisotopes. An increasing variety and volume of enriched isotopes will be needed for radionuclide production, for both fission and non-fission routes, to support the development of new treatments in the fight against cancer.

9 Securing the European Supply of 19.75% Enriched Uranium Fuel: 'PROPOSED OPTIONS', Euratom Supply Agency, May 2022, see: https://euratom-supply.ec.europa.eu/index_en

10 EU Fund & Tenders. Call for Proposal 'Preparatory phase for a European production capability to secure a supply of high-assay low-enriched uranium (HALEU) fuel': https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-euratom-2023-nrt-01-11

Europe needs to boost its capacity for the enrichment of source materials and stable isotopes.

Europe needs to boost its capacity for the enrichment of source materials and stable isotopes, which is only possible with considerable investment. The lack of EU-based electromagnetic or other suitable enrichment capability is a major concern. Similarly, recycling/reusing costly enriched source materials would help reduce waste and increase EU competitiveness but requires new dedicated installations to be built.

It is equally important to maintain and develop European capacity for the enrichment of stable isotopes through centrifugation, possibly combined with another method of enrichment. Developing cyclotron-based radionuclide production would increase the need for centrifugation-enriched materials, which could only be achieved by expanding European capabilities.

Yet another important missing element for maintaining the uninterrupted supply of medical radioisotopes is a system for monitoring supply and producing long-term forecasts. The ESA notes that such a system needs to cover a broader spectrum of radioisotopes and production methods and could be based on the experience of the European Observatory on the Supply of Medical Radioisotopes, which monitors Molybdenum-99/Technetium-99m supply.

2.2. ESA recommendations on the security of supply

The EU, its Member States, like-minded countries, utilities and the nuclear industry have been working to address dependencies in the nuclear field. In May 2022, the European Commission launched the REPowerEU plan, aiming to enhance energy security and strategic autonomy. Nuclear supplies are a crucial part of this transition [11] for EU Member States using nuclear energy.

Further efforts are needed by interested Member States to develop reliable supply chains to meet the growing demand for nuclear and new nuclear technologies, to achieve climate goals while maintaining energy sovereignty.

Further efforts are needed by interested Member States to develop reliable supply chains to meet the growing demand for nuclear and new nuclear technologies, to achieve climate goals while maintaining energy sovereignty.

Ensuring a secure supply of nuclear fuel from ore to final product is a key objective across the Euratom Supply Agency's activities.

In this section, ESA outlines a number of essential recommendations for guaranteeing a secure supply of nuclear materials and related services. It includes recommendations addressing vulnerabilities arising from the current geopolitical situation and enabling the expected expansion of nuclear energy production and non-power applications.

11 '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', from the REPowerEU plan.

Follow best practice in security of supply

Underpinning the stability and resilience of nuclear fuel and services supplies are a set of strategies that prioritise diversification and long-term planning. Utilities can reduce their dependence on individual providers and mitigate the risk of supply disruptions by diversifying their supply chains and contracting with a range of reliable suppliers. Long-term contracts provide a stable foundation for supply relationships, enabling utilities to plan and budget with confidence and enabling industry to invest in the required capacity. Adequate operational stocks, carefully managed and maintained, serve as a critical buffer against unexpected supply chain disruptions. These measures need to be underpinned by a robust risk-management framework, which identifies, assesses, monitors and mitigates potential risks to the supply chain.

Risk management

Energy regulators, safety regulators, grid operators and electricity holdings should factor the nuclear supply risk into their risk assessment and preparedness.

Nuclear utilities and fuel-cycle actors should implement a robust risk-management framework to minimise the risk of supply chain disruptions, ensure a stable and reliable supply of nuclear fuel, and support the continuous operation of nuclear power plants.

They should specify the acceptable level of exposure with respect to high-risk profile partners or operations/transactions and be mindful of possible interrelationships across energy products and interdependencies of supply chains (e.g. risk of storage and transport, origin of components and source material for components and parts). The risk factors to be considered in relation to security of supply include:

- changing Community and national decisions, regulatory frameworks;
- legal and economic ownership of suppliers;
- physical location and control of nuclear materials;
- geographical origin of supplies, considering the potential risks associated with different regions;
- risk profile of transactions or commercial partners and suppliers;
- supply logistics.

All market parties concerned should draw up and implement plans to mitigate identified risks. They should cooperate to strengthen mechanisms for data and information sharing on the evolution of factors affecting the supply of nuclear fuels and relevant products.

The security of energy supply should be monitored at different levels: at EU/Euratom level, at national, industry and utility level. It should be a coordinated effort to include all viewpoints and interests.

Diversification

Bundled supplies and/or relying on a single supplier at any stage of the nuclear fuel cycle hamper market functioning and transparency, lead to excessive dependence and make the utility vulnerable to adverse events.

Diversification is key to securing future deliveries and to minimising dependence on individual suppliers. Security of supply should preferably encompass:

- at least two different suppliers from like-minded countries, whenever possible at least one EU-based;
- different suppliers at each stage of the fuel cycle, considering legal and economic ownership;
- diverse geographical origin of the supplies and physical location of the nuclear materials;
- creating alternative routes and modes of transport to minimise reliance on single transport routes or modes.

Long-term contracts

Utilities should consider concluding multiannual contracts to cover most of their requirements for uranium and services. Long-term contracts add stability and predictability for the nuclear industry and electricity production. They help give a clear understanding of future demand and can foster industry investment in production capacity.

Supply contracts concluded for a period longer than 10 years are possible with additional authorisations.[12]

Adequate operational inventories

Utilities should maintain adequate inventories of nuclear materials in the EU and other low-risk locations to cover future requirements and should use market opportunities to increase stocks.

12 Article 60 of the Euratom Treaty.

Fuel supply chain actors should also maintain inventories to avoid interruptions in the nuclear fuel supply chain.

In building inventories, due care must be paid to determining the appropriate chemical-physical specifications and amounts, given the lead times in the fuel cycle steps. Stock should include fresh fuel in quantities that can respond to supply chain delays or interruptions.

EU Member States, producers and users are invited to take a coordinated approach, considering the financing and technical efforts involved.

Addressing vulnerabilities arising from the current geopolitical situation

Based on its analysis, the ESA concludes that, at least in the medium and long term, EU utilities' demand for natural uranium, fuel fabrication and related services face challenges and different degree of risks related to the geopolitical situation. In fuel fabrication, 100% reliance on a single design and supplier of VVER fuel remains to some extent a concern as all but one of the utilities concerned are moving forward with fuel diversification and have been building fresh fuel stocks to tide them over until their diversification process is completed. In the short term, a limited number of utilities remain contractually bound for all supply to a single supplier.

> EU utilities' demand for natural uranium, fuel fabrication and related services face challenges and different degree of risks related to the geopolitical situation.

In fuel fabrication, 100% reliance on a single design and supplier of VVER fuel remains to some extent a concern as all but one of the utilities concerned are moving forward with fuel diversification and have been building fresh fuel stocks to tide them over until their diversification process is completed. In the short term, a limited number of utilities remain contractually bound for all supply to a single supplier.

An analysis of the nuclear industry (converters and enrichers) indicates that the total open-market conversion and enrichment capacities may not be sufficient to cover the short-term residual needs if the services from current non-open market players such as Russia are no longer available. Building the additional conversion and enrichment capacity required could take several years and would entail significant investments.

Preparedness at EU and Member State level

Euratom should consider developing emergency policies and measures for crisis management, similar to those developed for other sources of energy. This could include maintaining EU industry capacity and essential services for EU users, building common emergency stocks, and reinstating a common purchase and distribution mechanism under the Euratom Treaty. This would ensure a coordinated response to supply chain disruptions and minimise the impact on EU utilities and users. Euratom would benefit from a coordinated approach to strategic stockpiling for emergency situations, mindful of the Euratom Treaty provisions and the special capital, financing and technical effort involved. The approach should give due consideration to securing adequate amounts of material at different stages of the fuel cycle (e.g. natural uranium, converted uranium, enriched uranium products and fuel assemblies).

> Euratom would benefit from a coordinated approach to strategic stockpiling for emergency situations.

National reserves or inventories of utilities dependent on a non-EU design and supplier should also include a number of reloads to tide them over until alternative fuel is available in the event of the fuel supply definitive interruptions.

Tackling supply chain vulnerabilities

Clear political and policy decisions at both EU, Euratom and Member State level are needed to tackle the supply vulnerabilities identified, in the interests of both power and non-power uses of nuclear energy.

Based on its analysis, the Agency believes that industry investment, particularly in enrichment and conversion capacities, would not be viable without some form of political commitment. The Agency therefore repeats its call for decision makers to consider the issue as a matter of utmost priority. Furthermore, action is needed to boost capacity in certain fuel-cycle technology for reprocessing, uranium and plutonium recycling, or to tackle dependence.

> Industry investment, particularly in enrichment and conversion capacities, would not be viable without some form of political commitment.

The EU, Euratom Member States, producers and users could benefit from an international multilateral approach involving all countries concerned to significantly reduce the exposure to and where possible to phase-out suppliers with a high-risk profile.

Lacking short-term reliable supplies, to cover residual requirements in this timeframe, utilities are recommended to consider concluding short-term or spot contracts, mindful of the potential risks. It is essential to conduct thorough due diligence to ascertain the economic and mining origins, and availability, of the materials in question. This approach enables early detection of vulnerabilities in the supply chain, allows for a more accurate assessment of risks associated with potentially unreliable sources, and facilitates the mitigation of those risks.

Monitor security of supply risks

The Commission, ESA and national authorities should continue to jointly monitor the implementation of nuclear supplies diversification plans. The focus should be on the VVER reactor fuel and on taking action to eliminate any risks or threats to the timely completion of these plans, while fully respecting the nuclear safety framework.

Market players should continue monitoring the market, taking into account origin and transit risks and carrying out contractual due diligence to manage their exposure to a changing market and avert security of supply vulnerabilities.

Diversification

The utilities and research reactor operators that depend on a single non-EU supplier design for fuel assemblies, components and spare parts should continue developing and implementing actions that cover all aspects of the diversification process.

Special attention should continue to be given to accelerating the market introduction of alternative fuel designs. In parallel it is essential to start developing alternative solutions for fuel designs and components, based on European intellectual property rights and a European supply chain.

Cooperation between industry, operators and regulators is vital to reduce the time to design and market alternative VVER nuclear fuel, further improving the security of supply, and giving due priority to nuclear safety.

> Special attention should continue to be given to accelerating the market introduction of alternative fuel designs.

In addition, given the regional concentration of uranium origin and that a number of utilities have a single non-EU supplier, the Agency stresses the need to source supplies from diverse jurisdictions and geographical origins.

Contract now for long-term needs

Long-term commitments are required to trigger investments that can enable increased conversion and enrichment capacity in the EU and/or EU like-minded countries.

At the same time, open market industry should bear in mind that excessively high prices could incentivise users to explore other supply options, defer the signing of long-term contracts or optimise the size of their inventories.

Enusa Juzbado Facility

Towards a stable long-term supply chain

Across the globe, there is growing interest in nuclear energy as a contributor to achieving the 2050 climate objectives. The 28th United Nations Climate Change Conference (COP28) acknowledged the importance of accelerating the deployment of low-carbon technologies including nuclear energy and saw 22 world leaders (12 from EU Member States) sign a pledge to triple nuclear energy capacity by 2050.

Several EU Member States have put forward initiatives to extend the operations of their power plants, to expand their capacity or to build new power plants. There is also active interest in developing new nuclear technologies such as small and modular reactors (SAMRs), also due to their application beyond power production such as district-heating or hydrogen production.

To enable nuclear expansion and developments, it is necessary to boost the availability of free-market capacity and new civil nuclear technologies.

To enable nuclear expansion and developments, it is necessary to boost the availability of free-market capacity and new civil nuclear technologies. However, the scope, time and specific technologies that will be deployed remain uncertain.

A clear strategy needed

In alignment with national objectives for energy security and energy mix choices, Member States that opt for nuclear energy generation should foster a stable environment that enables utilities and industry to make informed strategic and operational decisions. To achieve this, they should clearly specify:

- national objectives: setting explicit national nuclear energy goals and targets in the energy mix;

- technology and fleet development: providing a clear roadmap for the long-term operation, new builds, and development of new nuclear technologies, including investments and deployment strategies;

RRF EPZ turbine

©Ruden Riemens Fotografie

- supply security: specifying the conditions that nuclear utilities must meet to ensure a reliable and secure supply of energy.

This clarity will enable the nuclear industry to make informed decisions, driving investment, innovation and growth in the sector.

Support a coordinated approach

Built on a foundation of mutual trust in the implementation of the highest safety standards, a coordinated approach could streamline the licensing process for innovative reactor fuels designs, including alternative and advanced options, to boost efficiency and cooperation between national nuclear safety authorities.

> A coordinated approach could streamline the licensing process for innovative reactor fuels designs, including alternative and advanced options.

It is equally important to facilitate the alignment of related norms, standards and procedures to facilitate the development of the nuclear industry.

Increase indigenous sources of supply

> It will become increasingly crucial to reduce to the extent possible uranium imports and demand of fuel-cycle services as well as to promote a circular nuclear economy.

While the nuclear market expands, it will become increasingly crucial to reduce to the extent possible uranium imports and demand of fuel-cycle services as well as to promote a circular nuclear economy. To achieve this, Member States and market actors should:

- Consider prospecting for and exploiting mineral deposits domestically or in reliable jurisdictions, in a sustainable manner.
- Investigate the benefits and challenges of closing the nuclear fuel cycle, which may boost resource efficiency and reduce waste generation.
- Pursue a diversified range of solutions to enable the production and use of alternative and recycled uranium and plutonium products. This includes investing in EU-based technologies such as reprocessing, uranium and plutonium recycling, re-enrichment including of depleted material (e.g. tails), and their application in advanced reactors, including fast-breeder reactors and new generation reactors.

Supply of advanced and new reactor fuels

Interested Member States, utilities, SMRs/AMRs developers should consider drawing up reliable and trustworthy plans to adopt advanced or new technology reactor fuels requiring low-enriched uranium plus (LEU+), HALEU or other nuclear materials, and then liaise with ESA to form a consistent view of the future needs for such materials.

New builds

Particular attention should be paid when building new nuclear power plants using non-EU designs. To ensure that these plants are not dependent exclusively on a single non-EU supplier of nuclear fuel, any such investment must be conditional on being able to diversify the fuel design.[13] New builds should map out at an early stage the supply diversification strategy for fuel. Contract terms must expressly provide for the safety licensing and use of fuel assemblies from other suppliers, in particular by providing for the disclosure of fuel compatibility data and the testing of alternative fuel designs.

Maintain and advance technology and skills

The EU nuclear supply chain capacity must be adapted to meet evolving market and technological demands, requiring a significant scale-up of investment.

Furthermore, concerted efforts and initiatives are essential to attract competent workers and young graduates in the nuclear sector. This will enable the EU to maintain and expand a skilled workforce with the necessary technical expertise across the entire fuel cycle, from the front end to the back end.

Medical radioisotope supply chain

Alternative fuel for research reactors

Research reactor operators dependent on a non-EU supplier or fuel design should continue to prioritise the implementation of their diversification plans. Special efforts should be taken to push forward EU fuel design and production solutions, namely those coordinated through the Euratom research programmes. [14]

Cooperation between industry, operators and nuclear regulators is key to increase the efficiency of these projects.

Address HALEU vulnerability

Clear political decisions are needed at both EU and Member State level to tackle future HALEU supply vulnerabilities. The EU, national authorities, industry and users should explore all options [15] to achieve EU autonomy and the continued HALEU supply to Community users for medical and research purposes, making use of the ongoing process to develop ERVI under SAMIRA.

13 Communication from the Commission to the European Parliament and the Council, 'European Energy Security Strategy', COM(2014) 330 final, 28.5.2014.
14 Euratom Research and Training Programme: https://commission.europa.eu/funding-tenders/find-funding/eu-funding-programmes/euratom-research-and-training-programme_en
15 Securing the European Supply of 19.75% Enriched Uranium Fuel PROPOSED OPTIONS, Euratom Supply Agency (ESA), May 2022, see: https://euratom-supply.ec.europa.eu/index_en

> Clear political decisions are needed at both EU and Member State level to tackle future HALEU supply vulnerabilities.

Consideration should be given to building up EU production by capitalising on the domestic industry, its capacities, know-how and technology, and in particular on maintaining EU technical know-how on the metallisation process.

Efforts should be continued to develop transport packaging solutions and have them licensed across relevant markets.

Improve the security of supply of source materials and stable isotopes

The EU, Member States and industry should tackle foreign dependencies of supply of source materials and stable isotopes needed to produce medical radioisotopes. This will ensure that current patient needs are met and will support the development of future cancer treatments by:

- diversifying the sources of supply;
- recycling/reusing costly enriched source materials;
- maintaining and developing European capacity for the enrichment of source materials and stable isotopes, regardless of the method of enrichment.

Forecast and monitoring system

To provide patients with a reliable supply of medical isotopes for diagnosis and treatment, the EU, Member States, industry and nuclear medicine stakeholders should build on the experience of the European Observatory on the Supply of Medical Radioisotopes. They should create a system to monitor the security of supply of key medical radioisotopes, regardless of their production method, and produce long-term forecasts of requirements in the EU.

Such a system could provide decision makers and stakeholders with facts and information to shape strategy, develop policy and make investment decisions in the supply chain.

3. Overview of EU developments

3.1. Euratom

3.1.1. EU nuclear energy in the wider context of EU energy policy and geopolitical challenges

In 2023, the European Commission continued its work to ensure the safe use of nuclear energy for peaceful purposes in Member States that choose to use it. The Commission emphasised continuous improvements in nuclear safety, security, and radiation protection, in particular to contribute to the long-term decarbonisation of the energy system in a safe, efficient, and secure way.

Russia's war of aggression against Ukraine has caused significant disruptions to the world's energy-supply system. It has triggered price volatility and energy insecurity across the world with significant impacts and repercussions for the EU's energy system in particular.

Russia's war of aggression against Ukraine has caused significant disruptions to the world's energy-supply system.

In the past 2 years, the EU and its Member States have responded decisively to the crisis and pursued the objective of reducing their dependence on Russian fossil fuels and phasing out Russian energy imports by 2027. They are pursuing this objective through: (i) a reduction of energy consumption through energy efficiency and savings; (ii) an acceleration in the shift from fossil fuels to renewable and low-carbon sources of energy; (iii) diversification away from Russian fuel supplies, including Russian nuclear fuel and fuel-cycle services; and (iv) intensified efforts to secure supplies from alternative trusted suppliers.

The Commission and the Euratom Supply Agency (ESA) have worked closely with relevant stakeholders to promote diversification of supply. This has encouraged diversification in the supply of nuclear fuel for the Russian-designed VVER-type reactors in operation in Europe. In 2023, the Commission and the ESA continued their discussions with Member States operating VVER reactors (Bulgaria, Czechia, Finland, Hungary and Slovakia), which are currently dependent on Russian nuclear fuel. These discussions focused on how to accelerate the diversification of fuel supply for these reactors. Of the 5 concerned EU utilities operating these reactors, 4 had signed contracts by the end of 2023 for the supply of alternative nuclear fuels. The Commission and the ESA have continued to monitor the situation on the market for nuclear fuel and related services. They have also kept in regular contact with the Member States concerned, nuclear power plant (NPP) operators, and market players involved in the nuclear-fuel value chain as well as the relevant national nuclear safety regulatory authorities. Nevertheless, dependency on Russia still exists for certain medical radioisotopes and fuel for research reactors.

In parallel, and also in response to Russia's ongoing war of aggression in Ukraine, the Commission in 2023 continued to closely monitor the situation in Ukraine's nuclear facilities, most notably the Zaporizhzhia NPP. In order to promote greater sharing of information to aid the coordination of any response actions, the Commission led a benchmarking exercise (with the participation of Ukraine) to compare the results of radiological-dispersion modelling among potentially impacted neighbouring countries in the event of a release from the Zaporizhzhia NPP, which has been seized by Russia. In 2023, the Commission also showed support to Ukraine at the international level, including at the 8th and 9th Review Meeting of the Convention on Nuclear Safety, and during the elections to the International Atomic Energy Agency (IAEA) Board of Governors, which now also includes representatives from Ukraine.

Finally, the EU and its Member States continued to provide direct support to Ukraine in the area of nuclear safety and radiation protection in 2023. This support took the form of material assistance, in particular through the EU's Civil Protection Mechanism (UCPM) and the European Instrument for International Nuclear Safety Cooperation. In addition, the EU provided funding to the IAEA to support its activities in Ukraine, including the safety and security missions by IAEA experts to Ukraine's NPPs.

In 2023, with the European Green Deal in its fourth year of implementation and the REPowerEU strategy [16] complementing it, Europe continued to prove that it can deliver a united and decisive response to the global energy crisis.

Nuclear energy is included in the scope of several legal instruments that entered into force, were adopted, or were under negotiation in 2023. These legal instruments aimed to deliver on the European Green Deal objectives and included the reform of the Electricity Market Design (EMD), the proposal for the Net-Zero Industry Act, and the Complementary Delegated Act on EU Taxonomy.

In 2023, with the European Green Deal in its fourth year of implementation and the REPowerEU strategy complementing it, Europe continued to prove that it can deliver a united and decisive response to the global energy crisis.

In March 2023, the Commission adopted a package containing proposals for a revision of both the EMD [17] and the Regulation on Wholesale Energy Market Integrity and Transparency. This package introduces measures that: (i) incentivise longer-term contracts for the production of non-fossil-fuel power; and (ii) enable clean, flexible solutions (such as demand response and storage) to play a stronger role in the energy market. The aim of the package is to: (i) make electricity prices less dependent on volatile fossil-fuel prices; (ii) increase consumer protection; (iii) protect end-users from any potential price spikes; and (iv) accelerate the deployment of renewable and clean energy. Although the EMD primarily focuses on achieving a high level of penetration of renewable energy sources, it also recognises the role of nuclear power. The instruments set out in the revision of the EMD (contracts for difference [CfDs] and power-purchase agreements [PPAs]) are designed to be equally accessible for new projects in both nuclear and renewables. In some cases, CfDs may also be used for new investments to: substantially repower existing power-generating facilities, increase their capacity, or prolong their lifetime. CfDs and PPAs should benefit nuclear-energy projects by giving investors the necessary security to pursue new investments.

In March 2023, the Commission also adopted a proposal for the Net-Zero Industry Act. [18] This proposal aims to scale up the manufacturing of clean technologies by streamlining the regulatory framework, attracting investment, and creating better conditions for the use of those technologies. Small Modular Reactors (SMRs) and advanced technologies to produce energy from nuclear processes with minimal waste from the fuel cycle have been included in the Commission's proposal.

On 1 January 2023, the Taxonomy Complementary Climate Delegated Act [19] entered into force. Under strict conditions, it includes three specific economic activities in the area of nuclear energy in the list of economic activities covered by the EU Taxonomy (the EU Taxonomy is a list of climate-friendly and environmentally friendly investments). The criteria for these three specific nuclear activities are in line with EU climate and environmental objectives. Projects that meet these criteria will help accelerate the shift from solid or liquid fossil fuels (including coal) towards a net-zero, climate-neutral future.

As part of their decarbonisation agenda, a number of EU Member States are considering new nuclear technology options, such as SMRs. [20] Building on the work done in the EU SMR pre-Partnership over the past 2 years, the Commission

Borssele NPP

©Ruden Riemens Fotografie

16 REPowerEU (europa.eu): https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/repowereu-affordable-secure-and-sustainable-energy-europe_en
17 Electricity market design (europa.eu): https://energy.ec.europa.eu/topics/markets-and-consumers/electricity-market-design_en
18 Net-Zero Industry Act (europa.eu): https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/green-deal-industrial-plan/net-zero-industry-act_en
19 Commission Delegated Regulation (EU) 2022/1214 OJ L188/1, 15.7.2022
20 Small modular reactors (europa.eu): https://energy.ec.europa.eu/topics/nuclear-energy/small-modular-reactors_en

continued its efforts in 2023 to facilitate the establishment of the European SMR Industrial Alliance, paving the way for its launch in early 2024. To this end, the Commission co-organised an SMR stakeholder forum in October 2023 to review and debate the outcomes of the pre-Partnership work and chart the way forward. The main goal of the SMR Industrial Alliance is to facilitate and accelerate the development, demonstration, and deployment of SMRs in Europe by the early 2030s.

> The Commission continued its efforts in 2023 to facilitate the establishment of the European SMR Industrial Alliance, paving the way for its launch in early 2024.

The 16th edition of the European Nuclear Energy Forum (ENEF) took place in Bratislava on 6-7 November 2023. [21] The 2-day event, co-organised by the Commission and Slovakia (as the host country), proved once more to be a successful platform for a broad and open debate around the potential, opportunities, risks and challenges of the EU's nuclear ecosystem in the light of both the EU's climate ambition and the dynamic geopolitical environment. More than 250 representatives from various EU and global stakeholders contributed to the forum's discussions, addressing topics such as: (i) diversification across the nuclear value chain to promote the EU's security of supply and nuclear safety; and (ii) the back-end of the fuel cycle (with a focus on high-level waste disposal and decommissioning). During the ENEF and its associated events, the Commission's readiness to launch the European SMR Industrial Alliance was also reconfirmed by European Commissioner for Energy Kadri Simson.

European Nuclear Energy Forum

©Euratom Supply Agency

In 2023, the Commission also continued to monitor the correct and effective transposition and implementation by the EU Member States of the Euratom legal framework on nuclear safety, radioactive-waste management and radiation protection. As part of this monitoring work, the Commission also opened and pursued a number of infringement cases. In addition, the Commission took into account both its own exchanges with the Member States and the findings of the Commission's 2022 second report on the implementation of the amended Nuclear Safety Directive. [22] This report highlighted the good level of implementation of the Directive's obligations and made recommendations for further improvements. The Commission's monitoring of the transposition and implementation of the framework has focused on several priority areas (regulatory independence, nuclear-safety objectives, and safety culture).

The Commission also continued its dialogue with the Member States to ensure appropriate implementation of the Spent Fuel and Radioactive Waste Directive. In 2023, four infringement cases were closed. The Commission did not issue any reasoned opinions on this Directive in 2023, and no new infringement cases were launched.

3.1.2. Radioactive waste management and nuclear decommissioning

In 2023, the Commission prepared its third report to the European Parliament and the Council on the implementation of Council Directive 2011/70/Euratom on the responsible and safe management of spent fuel and radioactive waste. This report is expected to be formally adopted in 2024.

The Commission is now preparing its fifth report to the European Parliament and the Council on the implementation of Council Directive 2006/117/Euratom on the supervision and control of shipments of radioactive waste and spent fuel, based on the Member States' national reports. [23]

21 16th European Nuclear Energy Forum: https://energy.ec.europa.eu/events/16th-european-nuclear-energy-forum-2023-11-06_en
22 COM/2022/173 final
23 This report is expected to be formally adopted in 2024 or in the beginning of 2025.

On the Nuclear Decommissioning Assistance Programmes (NDAPs) in the multiannual financial framework for 2021-2027, a budget of EUR 1.18 bn [24] was allocated to support decommissioning activities in Lithuania, Bulgaria, Slovakia, and the JRC facilities. The NDAPs progressed in 2023 and continued to reduce nuclear and radiation-safety risks for the concerned disused reactors. In Ignalina (Lithuania), following the removal and safe storage of fuel assemblies, the programme progressed in 2023 with preparations for the dismantling of the reactor cores. Substantial progress was also achieved in Bohunice (Slovakia), where the dismantling of the primary circuit in both units was completed, and only a final project in the programme (the demolition of the reactor buildings and final remediation) remains to be procured. In Kozloduy (Bulgaria), work started in 2023 on the dismantling of large components and equipment, such as the main circulation pumps and valves, following their decontamination. At the same time, the construction of phase 1 of the Bulgarian national disposal facility for radioactive waste was almost finalised.

3.1.3. Emergency preparedness and response

In the field of nuclear-emergency preparedness and response (EP&R), the Commission ensured the continuous operation of both: (i) the European Community Urgent Radiological Information Exchange (ECURIE) system for the exchange of urgent information in the event of a radiological emergency; and (ii) the European Radiological Data Exchange Platform (EURDEP) system for the exchange of radiation-monitoring data. The Commission also successfully carried out several EP&R tests and exercises in 2023. These tests and exercises included the annual ECURIE Exercise (ECUREX 2023), run in cooperation with national competent authorities, to test communication channels and Member States' response capacity. Participation in ECURIE was further expanded in 2023 with the accession of Serbia to the system. The Directorate-General for Energy also established enhanced cooperation with Ukrainian EP&R competent authorities in 2023.

3.1.4. External dimension of nuclear energy policy

In 2023, the Commission remained engaged in strengthening nuclear safety globally through close collaboration with international organisations (such as the IAEA and the OECD's Nuclear Energy Agency (NEA)) and non-EU countries, including countries neighbouring the EU.

Nuclear safety in the EU neighbourhood (i.e. the countries close to – but not members – of the EU) was pursued in 2023 through the post-Fukushima nuclear-safety stress tests conducted by the European Nuclear Safety Regulators Group (ENSREG) with the support of the Commission. Following the completion of the stress-tests peer review of the Belarusian NPP in Astravets, ENSREG was able to proceed with a peer review of the stress tests on the project to build an NPP at Akkuyu on the southern coast of Türkiye. The peer-review team completed a desk-top review of Türkiye's national stress-test report, and complementary discussions with Türkiye's national regulatory authority took place in May 2022. The full peer-review mission to Türkiye is scheduled to take place in the second quarter of 2024, depending on progress at the construction site. [25]

In 2023, much of the attention in the international agenda was paid to the impact of the Russian war of aggression in Ukraine – both on Ukraine itself and on the EU. Ukraine's nuclear energy sector has been significantly affected by Russia's military actions. Nuclear-safety developments in Ukraine were one of the main concerns for the Commission and ENSREG, both of which were regularly informed about the situation on the ground throughout the year by the Ukrainian nuclear safety regulator SNRIU. Because of the increased risk of a radiological incident or accident, the Commission continued to work with the European nuclear-safety and radiation-protection authorities in ENSREG, the Western European Nuclear Regulators' Association and the Heads of the European Radiological Protection Competent Authorities.

24 The EU's 2021-2027 long-term budget and NextGeneration EU, Facts and Figures (p46): https://op.europa.eu/en/publication-detail/-/publication/d3e77637-a963-11eb-9585-01aa75ed71a1

25 It actually took place in May 2024.

3.1.5. Cooperation with the United Kingdom in the nuclear field (post-BREXIT)

Following the successful conclusion of the Euratom/UK Nuclear Cooperation Agreement (NCA) at the end of 2020, the Commission and the United Kingdom signed detailed technical administrative arrangements for the implementation of the Euratom/UK NCA in January 2022.

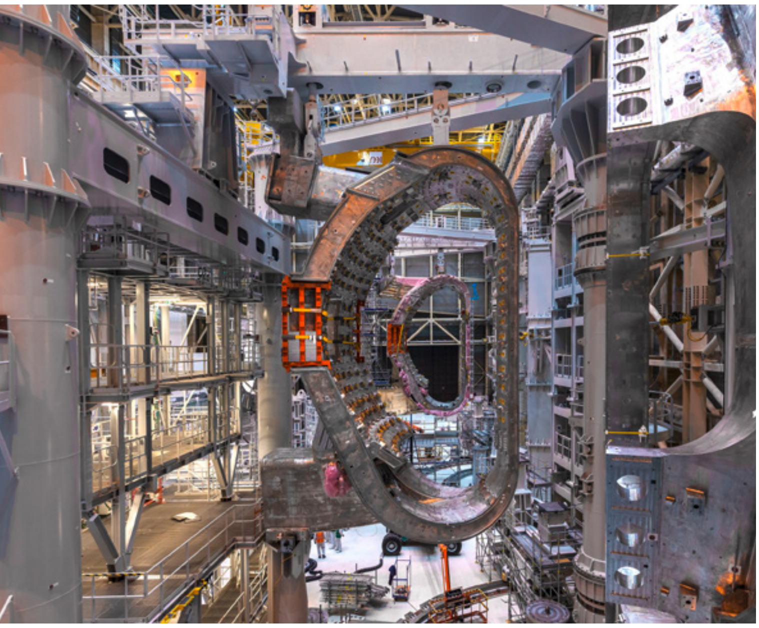
In accordance with the provisions of the NCA, the United Kingdom has participated as an observer in the work of ENSREG and the Group of Experts referred to in Article 31 of the Euratom Treaty and continues to provide data to the EURDEP. The Commission has also invited the United Kingdom to take part in the ECURIE system. The United Kingdom has still to complete the required internal approval process for this.

3.1.6. ITER and fusion energy

Throughout 2023, the Directorate-General for Energy continuously supported: (i) the construction of ITER, (an experimental device for magnetically-confined fusion designed to prove the feasibility of fusion as a large-scale and carbon-free source of energy); and (ii) the development of fusion energy more broadly.

The construction of ITER involves many first-of-their-kind challenges, which have led to delays in the project's progress. To address the accumulated delays and ensure that the ITER project delivers its expected results, comprehensive changes in the project were implemented in 2023. These changes include the starting of work on: (i) a new organisational structure for the ITER Organisation (IO); (ii) the revision and update of all of the IO's critical assembly and installation contracts; and (iii) a dialogue with the French nuclear safety regulatory authority, ASN, on a staged safety demonstration.

Vacuum vessel sectors at ITER



©ITER Organization

Due to the delays in the construction and commissioning of ITER, the current ITER baseline (drafted in 2016 and which set out the scope, schedule and estimated cost of the project shared between ITER members) cannot be maintained. The IO is now working with ITER members' domestic agencies (DAs), including the European DA Fusion for Energy (F4E), on drawing up a new baseline. The new baseline will provide details on a phased approach to assembly and operation to both reduce operation risks and minimise delays to the start of the ITER nuclear phase. It should be presented to the ITER Council in June 2024.

Despite ITER's challenges and the recent growth in private investments in a variety of fusion-design approaches, ITER remains not only highly relevant, but the cornerstone of global efforts towards the commercialisation of fusion energy.

In October 2023, the biggest experimental fusion device to date, JT-60SA, achieved a tokamak plasma for the first time. JT-60SA (Japan Torus-60 Super Advanced) is a fusion device resulting from an international science agreement between Europe and Japan, known as the Broader Approach, signed in 2007. The mission of JT-60SA is to support research for ITER to meet its technological goals and provide knowledge for the transition from ITER towards demonstration reactors. JT-60SA is hosted at Japan's National Institutes for Quantum Science and Technology, located in the city of Naka.

3.1.7. Euratom safeguards

'Euratom safeguards' is the legal and technical term to describe all aspects of the nuclear-material supervision system under the exclusive competence of the Euratom Community, established by the Euratom Treaty and operated by the European Commission on behalf of the Community. The Directorate-General for Energy is the Commission DG responsible for Euratom safeguards. It implements Euratom safeguards by means of a set of verification activities ensuring that civil nuclear materials in the EU 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 managed appropriately and used peacefully in the EU.

In 2023, 99.83% of all nuclear materials under Euratom safeguards were subject to both accountancy and physical verifications. The Commission continued to work in close cooperation with the IAEA as part of the implementation of the two multilateral agreements [26] and their respective additional protocol. Some of this work focused on the implementation of the 'safeguards by design' concept, integrating relevant safeguard considerations into the design phase of nuclear installations.

As a result of applying Euratom safeguards under the Euratom Treaty, no evidence was found in 2023 suggesting that nuclear materials were diverted from their intended uses in the EU. All the safeguards' obligations assumed by the Euratom Community under both multilateral agreements concluded with the IAEA and bilateral agreements with non-EU countries were complied with.

As a result of applying Euratom safeguards under the Euratom Treaty, no evidence was found in 2023 suggesting that nuclear materials were diverted from their intended uses in the EU.

Finally, the Commission adopted a proposal in 2023 for a Council Decision approving a Commission Regulation (Euratom) on the application of Euratom safeguards (COM/2023/793). The proposal includes a draft revised Commission Regulation (Euratom) on the application of Euratom safeguards which presents adjustments, in line with the conclusions of its evaluation conducted in 2022, to better reflect recent and expected developments in the nuclear industry.

3.1.8. European Commission research and innovation programmes

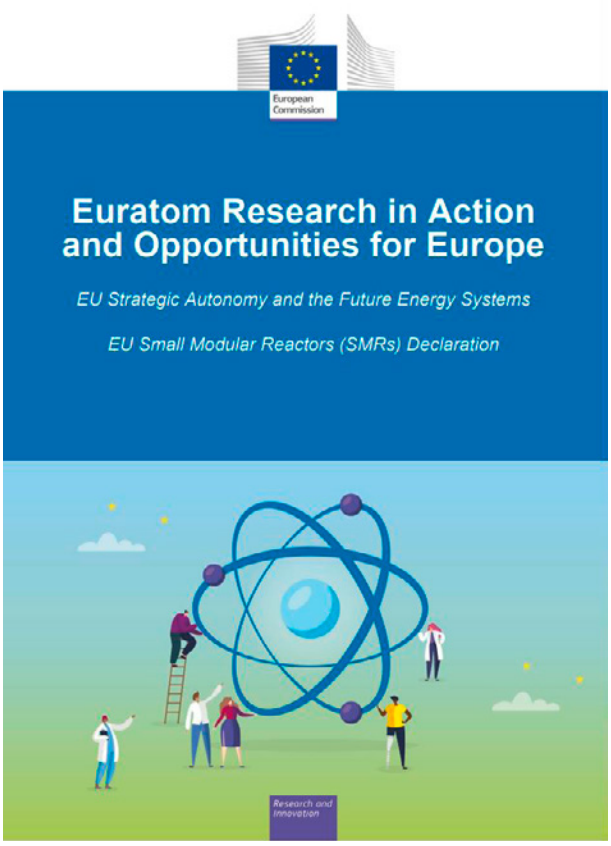
Actions launched and managed in 2023 by the European Commission under the Euratom research and training programme play an important role in maintaining strong European skills in nuclear research and innovation. The programme helps to ensure the highest standards of safety for existing and future nuclear installations. It is also crucial for developing fusion energy, as well as medical and other applications of ionising radiation.

Following the adoption of the Euratom work programme for 2023-2025, [27] the Commission launched a call for proposals, making EUR 132 million available for research to improve the EU's security of energy supply while ensuring the highest safety standards. The call for proposals sought applications for research enabling: (i) the long-term operation of existing nuclear power plants; (ii) the safety of SMRs; (iii) the development of nuclear materials; and (iv) the safe management and disposal of radioactive waste (EURAD). [28] The call also aimed to further develop the EU's open strategic autonomy in other applications of ionising radiation, including in the medical field, in critical raw materials and in the circular economy.

The Commission launched a call for proposals, making EUR 132 million available for research to improve the EU's security of energy supply while ensuring the highest safety standards.

26 INFCIRC/193 and INFCIRC/290 respectively between IAEA, EURATOM and EURATOM's non-nuclear weapon Member States and between IAEA, EURATOM and France.
27 Euratom Research and Training Programme: https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/euratom/wp-call/2023-2025/wp_euratom-2023-2025_en.pdf
28 Eurad (European Joint Programme on Radioactive Waste Management): https://www.ejp-eurad.eu/

Euratom Research in Action and Opportunites for Europe



@DG RTD

At the launch event for the call, the EU nuclear stakeholders and Mariya Gabriel, the former European Commissioner for Innovation, Research, Culture, Education and Youth signed a declaration on 'EU SMR 2030: Research & Innovation, Education & Training'. [29] The declaration focused on the key role of research, innovation, education and training for the safety of SMRs. It also called for further optimisation of Member States' actions on SMRs to attract the best talent in the field and to develop the most advanced and safe nuclear technologies.

Following an ad hoc call, the Commission awarded a grant for EUR 10 million in 2023 to launch an action to both carry out the necessary safety analyses/tests and put in place procedures needed to license VVER nuclear fuel manufactured by suppliers outside Russia. The APIS project [30] is also addressing the issue of security of fuel supply to Russian-designed VVER reactors in the EU and Ukraine. The operation of these reactors currently depends mainly on Russian-produced nuclear fuel. The sanctions introduced after Russia's invasion of Ukraine made it necessary to strengthen the nuclear-fuel security of supply for these reactors.

In the field of radiation protection, the European partnership for radiation-protection research PIANOFORTE launched a call [31] in 2023 with the objective of increasing the knowledge base and fostering innovation within the domain of radiation protection. Out of a total of 24 proposals submitted, 9 projects were selected for funding.

In August 2023, the Euratom-funded project EURAMED Rocc-n-Roll developed a strategic research agenda and roadmap [32] for medical applications of ionising radiation based on a patient-centric approach. The roadmap aims to promote better and more personalised healthcare to improve patients' life expectancy and quality of life, which is one of the cornerstones of the SAMIRA action plan, [33] the Horizon Europe activities and Commission initiatives (Europe's Beating Cancer Plan and the Cancer Mission).

In fusion research, the Euratom co-funded partnership EUROfusion successfully achieved the research goals of its third deuterium-tritium experimental campaign (DTE3) [34] at the Joint European Torus device in 2023. The experiments explored fusion processes and control techniques under similar conditions to – and in preparation for – future fusion power plants. This marks an important step forward in our understanding of fusion plasma. These efforts play a key role in the pursuit of a net-zero plan for Europe by developing fusion as a reliable and sustainable energy source.

In Granada, Spain, the Commission signed a grant in 2023 for the preparatory phase of IFMIF-DONES, [35] a unique neutron-irradiation facility for the study of fusion materials and systems under conditions that are similar to those in a fusion power plant.

In addition, the Commission launched a call in September 2023 for the 2024 edition of the SOFT Innovation Prize, [36] a prize recognising and showcasing innovation in fusion research and rewarding both excellent research with market potential and the researchers and industries involved.

29 Euratom research in action and opportunities for Europe: https://op.europa.eu/en/publication-detail/-/publication/e7c3556c-d29d-11ed-a05c-01aa75ed71a1/language-en
30 APIS (Accelerated Program for Implementation of secure VVER fuel Supply) project: https://cordis.europa.eu/project/id/101114673
31 Pianoforte Partnership: https://pianoforte-partnership.eu/calls/open-call-2023
32 EURAMED rocc-n-roll unveils SRA and Roadmap: https://roccnroll.euramed.eu/euramed-rocc-n-roll-unveils-sra-and-roadmap/
33 SAMIRA Action plan: SWD(2021)14
34 Joint European Torus-DTE3: https://euro-fusion.org/eurofusion-news/dte3-results/
35 IFMIF-DONES: https://ifmif-dones.es/
36 SOFT Innovation prize (europa.eu): https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/prizes/soft-innovation-prize_en

3.1.9. Activities of the Joint Research Centre

The Euratom research and training programme for 2021-2025 continues to drive the European Atomic Energy Community's efforts in nuclear research and training. This programme emphasises the continuous improvement of nuclear safety, security, and radiation protection, complementing Horizon Europe's objectives, in the context of the energy transition. In 2023, the JRC updated its organisational structure to better reflect JRC activities and priorities. In 2023, the JRC also celebrated the 60th anniversary of its nuclear safety and security activities. The celebration included several events at various JRC nuclear sites, together with a high-level event in Karlsruhe attended by more than 200 participants, including: (i) Member State representatives: (ii) European, national and regional German authorities; (iii) international partners; and (iv) industry representatives.

> In 2023, the JRC celebrated the 60th anniversary of its nuclear safety and security activities.

JRC nuclear work programme

The JRC's 2023-2024 work programme was developed with a focus on collaboration and the JRC's core strengths to better anticipate, integrate in, and impact on EU policies. The work programme contains three workstreams (known as 'portfolios' in the work programme) in the nuclear sector. These portfolios address:

(i) research, training, and knowledge management to promote the safety of nuclear technology for current and advanced systems, including the management of both radioactive waste and spent fuel;
(ii) SMRs, in particular the integration of safety, security and safeguards aspects; and
(iii) support for nuclear-legislation compliance.

Other topics (such as nuclear security; nuclear safeguards and non-proliferation; non-power applications of nuclear science and technology; and environmental radiation monitoring) are integrated into five mixed portfolios alongside non-nuclear research.

Recognising the critical role of medical radionuclides, the JRC is leading initiatives to secure their sustainable supply, supporting EU policies like SAMIRA and the Beating Cancer Plan. The JRC's research in this area focuses on novel radionuclide technology, specifically alpha emitters for targeted alpha therapy. Collaborations with global partners and exploration of alternative production methods exemplify the JRC's pioneering work in this field. In 2023, the JRC launched an initiative on nuclear medical applications, kicked off by a high-level nuclear roundtable convened by former Commissioner Mariya Gabriel and followed up by three stakeholder workshops on:

(i) 'Translating radio diagnostic cancer research into clinical practice' at JRC Ispra;
(ii) 'Competencies for medical applications or nuclear science' at JRC Petten; and
(iii) 'Research and innovation for sustainable medical radionuclide supply in the EU' at JRC Karlsruhe. These events, held at the JRC's nuclear sites, explored the main challenges faced by medical applications of nuclear technology, particularly roadblocks preventing technological advances in nuclear medicine from reaching European patients.

In 2023, the JRC continued to provide operational analyses to safeguards authorities. These included analyses based on the JRC's research and development of technologies, methodologies and standards for more effective and efficient safeguards to address different parts of the nuclear fuel cycle from enrichment to final disposal (including the supply of certified reference materials). The JRC's R&D results in this area are transferred to – and made operational by – both Euratom safeguards and the IAEA. The JRC operates the Euratom safeguards analytical on-site laboratory at the Orano reprocessing plant in La Hague (France), where JRC experts conduct around 600 analyses every year. The JRC also provides dedicated training to safeguards inspectors (training 60 inspectors in 2023) and continues to provide scientific and technical support (experts and infrastructure) to the IAEA on safeguards through the European Commission support programme.

In 2023, the direct actions of the Euratom programme implemented by the JRC resulted in the publication of 108 scientific articles in peer-reviewed journals and one doctoral thesis. The JRC also delivered other relevant technical outputs in 2023, including:

(i) 7 sets of reference materials and reference methods;
(ii) 2 outputs which contributed to changes in international standards;
(iii) 5 technical systems, all of them for safeguards; and
(iv) 2 scientific datasets and databases.

The JRC also organised a side event during the IAEA's General Conference in September 2023. The side event was entitled 'Providing the best nuclear data for tomorrow's nuclear solutions' and saw relevant bodies discuss challenges and possible ways forward.

The JRC has continued to provide technical and scientific support for monitoring:

(i) the implementation of Euratom Council Directives;

(ii) the implementation of EU international instruments on nuclear safety and safeguards; and
(iii) instruments related to nuclear and radiological security.

It also continued its cooperation with EU and international partners.

Since the start of the Russian war of aggression on Ukraine, the JRC, in close collaboration with relevant partners, has been supporting the European Commission by analysing nuclear and radiological threats, monitoring environmental radiation, and assessing the impact of trade-restrictive measures.

Education, training, and infrastructure access

The JRC's commitment to nurturing nuclear skills can be seen in its comprehensive education and training programmes, the open access it gives researchers to its facilities, and its support for staff mobility. The actions of the JRC have directly benefited researchers and students across Europe, especially since the resumption of activities following pandemic-related restrictions. The JRC's nuclear education and training initiatives, which include training schools, workshops, and lectures (given in person, online or in a hybrid format) support EU policy priorities and help to maintain and develop the EU's nuclear skills and expertise. In 2023, the JRC delivered 13 training courses in the field of nuclear safety, 9 on nuclear security, 8 on nuclear safeguards, 1 on strategic trade control, 10 on nuclear decommissioning and waste management, and 17 on non-power applications of nuclear science and technology. Since 2021, the JRC has:

(i) carried out 100 experiments on actinide materials;
(ii) developed codes and standards for components and materials; and
(iii) conducted radioactivity measurements.

These experiments and measurements, and this development of codes and standards, were carried out by external users from 17 Member States under the Euratom Open Access framework.

In summary, the JRC's activities in 2023 have been integral to advancing nuclear research and innovation, contributing to medical advancements, and supporting EU policies. As the JRC adapts to emerging challenges and continues to optimise resources, it remains a cornerstone of the EU's commitment to the safe and secure use of nuclear science and technology.

> The JRC's activities in 2023 have been integral to advancing nuclear research and innovation, contributing to medical advancements, and supporting EU policies.

3.2. Country-specific developments

During 2023, 103 commercial nuclear power reactors were operating in 13 EU Member States. At the end of 2023, following the permanent shutdown of the last three German power plants on the 15th of April and the connection to the grid of one unit in Slovakia on 31st January, 100 nuclear power reactors were operating in 12 EU Member States. There were two reactors under construction/commissioning in France and Slovakia (see Table 7).

The total net capacity at the end of 2023 was 96 664 Mwe.

Table 5. Nuclear power reactors in the EU-27 in 2023

Country	Reactors in operation (under construction)	Net capacity (MWe) (under construction)
Belgium	5	3 928
Bulgaria	2	2 006
Czechia	6	4 212
Finland	5	4 394
France	56 (1)	61 370 (1 650)
Germany (*)	3	4 055
Hungary	4	1 916
Netherlands	1	482
Romania	2	1 300
Slovakia (**)	5 (1)	2 308 (471)
Slovenia (***)	1	688
Spain	7	7 123
Sweden	6	6 937
Total EU-27	**103 (2)**	**100 719 (2 121)**

(*) Permanent shutdown of the last three power plants (Emsland, Isar 2 and Neckarwestheim 2) on 15 April 2023
(**) Mochovce-3 first grid connection took place on 31 January 2023.
(***) The Croatian power company HEP owns a 50% stake in the Krško NPP in Slovenia.

Austria

The construction and operation of nuclear power installations in the country is prohibited by the Federal Constitutional Act for a Non-nuclear Austria.

Belgium

In January, Tihange NPP reactor 2 was shut down in accordance with the Belgian nuclear phase-out plan.

A decision was taken by the Belgian federal government in 2022 to enter into negotiations with the nuclear operator, with a view to extend the operation of Doel 4 and Tihange 3 reactors to operate until 2035 and environmental impact assessment of this 10-year extension was launched.

In December 2023, ENGIE and the Belgian federal government signed an agreement setting out the conditions for the 10-year extension of the operational life of these two reactors. This agreement aims to ensure a balanced distribution of risks between the two parties to ensure the restart of the Doel 4 and Tihange 3 reactors as early as November 2025, and remove uncertainties over possible changes to rules on the management of nuclear waste and spent fuel.

In June, the IAEA carried out an IRRS mission in Belgium and concluded that the Belgian government and national regulatory bodies are committed to the continuous improvement of nuclear and radiation safety. The IAEA IRRS group also issued one recommendation to Belgium, saying that that there was a need to identify and secure sufficient financial resources and skilled staff for the energy regulator considering Belgium's changing nuclear-energy context.

In December, the IAEA carried out an ARTEMIS mission in Belgium, taking into account the results from the June IRRS mission in line with its obligations under the 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. [37] The IAEA's conclusions following its December visit confirmed that Belgium was committed to the safe management of its radioactive waste and spent fuel, while noting opportunities to improve national

37 Council directive 2011/70/Euratom

Nuclear Power in the EU in 2023

15 000 tU/y
conversion capacity

13 364 tU
conversion purchased

16 200 tSW/y
enrichment capacity

12 260 tSW
enrichment purchased

14 357 t
uranium purchased

37 655 t*
uranium inventory

96 664 MWe*

Total nuclear capacity

587.6 TWh
electricity generated

100
operating reactors*
in **12 MS**

*) 31 December 2023

policies and arrangements for the final disposal of nuclear waste and spent fuel. [38]

Bulgaria

Since 2019, Bulgaria has been engaged in a programme to diversify its supplies of fresh nuclear fuel. Its activities as part of this programme continued during the reporting period in accordance with the contract signed in 2022 between Kozloduy NPP and Westinghouse Electric Sweden AB for the supply of fresh nuclear fuel for Unit 5 of the Kozloduy plant in 2024-2033. In 2023, an application was submitted by Kozloduy NPP to Bulgaria's Nuclear Regulatory Agency requesting permission to use a new type of nuclear fuel, RWFA, manufactured by Westinghouse.

Furthermore, following EURATOM's policy decision to diversify nuclear fuel supplies based on the European energy security strategy, a 10-year contract was signed on 24 March 2023 with the French company Framatome for the supply of fresh nuclear fuel and related services for Unit 6 of the Kozloduy NPP. The first delivery is expected in November 2025.

In January, the National Assembly of the Republic of Bulgaria adopted a decision authorising the Council of Ministers to conduct negotiations with the government of the United States of America to conclude an Intergovernmental Agreement for the construction of new nuclear capacity at Unit 7 of the Kozloduy NPP using AP1000 technology.

In a decision of October 2023, Bulgaria's government approved in principle the construction of a new unit at Kozludy NPP, Unit 8. This decision also mandated the Minister of Energy to act in further negotiations for the construction of Unit 7 of the Kozloduy NPP using AP1000 technology.

Croatia

In 2023, Croatia continued its preparations for the disposal of low- and intermediate-level radioactive waste from the Krško NPP. The country also expressed interest in developing a second reactor at the Krško site and in supporting the development of SMR technology.

In June, an IAEA review team carried out an ARTEMIS mission in Croatia. Following the visit, the ARTEMIS team concluded that Croatia was committed to addressing the challenges of managing its radioactive waste. In addition, the IAEA team identified some specific areas where they suggested Croatia could make additional efforts, such as in the development of arrangements for the safe and secure centralised storage of radioactive waste.

Czechia

A new national energy and climate plan was drafted and submitted to the European Commission in 2023. According to the plan, nuclear power will be, alongside renewable sources, one of the basic pillars of the country's future electricity-generation portfolio. This was also confirmed by a new national energy policy, which is in the final stage of the approval process. The government is considering the construction of four new large nuclear units in total, Units 5 and 6 at Dukovany and Units 3 and 4 at Temelín. Czechia also expects to construct several SMRs. In 2023, the Czech Ministry of Industry and Trade approved a plan for small and medium-sized reactors.

In 2022, Czechia launched a tender to select the engineering, procurement and construction (EPC) contractor for a new nuclear unit of up to 1.2 GW at the Dukovany plant site. Initial bids were submitted in November 2022 by EDF, KHNP and Westinghouse. Based on technical and commercial discussions and clarifications, the bidders submitted updated initial bids in November 2023, containing binding bids for the construction of the Dukovany Unit 5 and non-binding indicative bids for the construction of all 4 units across both Dukovany and Temelín. [39]

In 2023, CEZ, one of Czechia's largest electricity utilities, followed the SMR programme approved by its Board of Directors. This resulted in additional technical visits made by CEZ to each of the seven pre-selected SMR vendors to review the progress in technology development since 2022 and receive an update on the activities of each vendor. In 2023, CEZ also continued its studies at the Temelín nuclear site and the currently non-nuclear sites of Dětmarovice and Tušimice to assess the suitability of all three sites for hosting an SMR. The studies included considerations of both natural and human aspects. Both vendor selection and siting activities will continue in 2024.

In line with the ESA's diversification policy, a long-term contract with Westinghouse for the supply of nuclear fuel assemblies to the Dukovany NPP was awarded in March 2023, with the first delivery of assemblies planned for 2024 and loading into the reactor planned for 2026.

In May, the IAEA's IRRS mission confirmed Czechia's commitment to maintaining and strengthening its strong regulatory framework for nuclear and radiation safety. Some areas for improvement were identified by the IRRS team, mainly on the need for rules to ensure appropriate regulatory oversight of the safety of new facilities and activities planned

38 Integrated Review Service for Radioactive Waste and Spent Fuel Management, Decommissioning and Remediation: https://www.iaea.org/sites/default/files/documents/review-missions/final_report_artemis_belgium.pdf

39 In January 2024 the government decided to request also binding bids for the construction of up to 4 units. The complemented bids were submitted on April 30, 2024.

in the national strategic energy plans. The IRRS mission was supported by an IAEA ARTEMIS review mission in October, which stated that Czechia had established a solid basis for the safe and responsible management of radioactive waste and spent fuel. The ARTEMIS team also provided some recommendations and suggestions on both the plans for a deep geological repository and ensuring readiness for a potential expansion/prolongation of the country's nuclear power programme.

Estonia

Estonia is considering SMRs as a solution to produce climate-neutral electricity and set up a working group on nuclear energy in 2021 for this purpose.

In October 2023, Estonia hosted a Phase 1 mission of the IAEA's Integrated Nuclear Infrastructure Review. As a result, [40] of the mission, Estonia received 3 recommendations and 3 suggestions, and a further 3 good practices were identified for the country.

The key areas for further action recommended by the IAEA include completing Estonia's comprehensive report. This report will serve as the basis for the Government and Parliament to make a decision about introducing nuclear energy in Estonia. IAEA's suggestions also include beginning the preparation and coordination of the country's nuclear power program, starting with the legislative and regulatory framework.

In December, the working group on nuclear energy presented its final comprehensive report [41] to the government on the possibilities for implementing nuclear energy in Estonia.

The decision as to whether to construct nuclear power in Estonia will be taken in 2024.

Finland

In April, Finland held parliamentary elections and formed a new government. The government's programme includes nuclear as an important element, and specifically states the country's need for more nuclear energy. The programme also recognises the urgency of renewing Finland's nuclear energy legislation and regulations to enable new nuclear energy projects and the use of new technologies, such as SMRs.

On April 16, the Olkiluoto 3 NPP started regular electricity production after completing its test production phase. The operating licence is valid until 2038 and with the new unit online, nuclear power now provides more than 40% of the country's electricity.

In February, both units of the Loviisa NPP were granted an extension to their operating licences, which allows them to produce electricity until the end of 2050.

To diversify the fuel supply to the Loviisa NPP, operators are currently testing new Westinghouse fuel. In December 2023, it was reported that this testing is progressing well, with one test assembly in one of the reactors since the summer.

France

In February and July, President Macron convened a Nuclear Policy Council (CPN). These meetings provided an opportunity to take stock of French nuclear issues as a whole, both in the short and long term and to set up orientations for nuclear policy:

- With a view to producing decarbonised and competitive electricity over the long term, studies are launched to prepare for the operation of existing power plants till 60 years and beyond, as long as all applicable safety requirements are met, under the control of the French nuclear safety authority;
- Within the administration, the creation of the Interministerial Delegation for the New Nuclear (DINN) aims to coordinate all the actors mobilized to ensure that the deadlines and objectives of the construction programme of 6 new EPR2 nuclear reactors will be respected;
- The Bugey site has been selected for the third pair of EPR2 reactors, after Penly and Gravelines sites. Technical studies and analyses will continue at the Tricastin site, with a view to building future nuclear reactors.
- The development of small modular reactors (SMR) and innovative reactors (AMR) is also crucial and one of the challenges of the major investment plan called "France 2030";
- The role of the Atomic Energy Commission (CEA) will be strengthened and its resources significantly increased so that it can provide support and backing for the development of these projects. It will also support the government in steering and programming nuclear research;
- The pursuit of investment to finalize the construction of the Jules Horowitz research reactor (JHR) to be operational by 2032-2034 was approved;
- As regards the nuclear fuel cycle, an in-depth work stream is launched, especially as regards the perspectives for spent fuel treatment and valorization;

40 Mission report on the integrated nuclear infrastructure review (INIR) - Phase 1: https://kliimaministeerium.ee/sites/default/files/documents/2024-01/Rahvusvahelise%20Aatomienergiaagentuuri%20INIR%20missiooni%20aruanne.pdf
41 Possibilities for the implementation of nuclear energy in Estonia: https://kliimaministeerium.ee/sites/default/files/documents/2024-02/Final%20Report%20-%20Possibilities%20for%20the%20Implementation%20of%20Nuclear%20Energy%20in%20Estonia.pdf

- A major training plan for nuclear jobs is launched.

In June, a law aiming at accelerating the construction of new nuclear facilities near existing nuclear sites was promulgated. The law will allow for the reduction of the time lapse related to administrative procedures and simplify them, by centralizing the authorizations necessary to the construction and anticipating non-nuclear preliminary works.

In September, the Minister for Energy Transition chaired, along with the Nuclear Energy Agency of the OECD, the "Roadmaps to New Nuclear" conference. The aim was to provide a forum to governments and industrial actors that would enable participants to implement joint cooperation on nuclear energy on new builds projects.

In March 2023, EDF announced the creation of its subsidiary NUWARD, to boost the development of its NUWARD™ Small Modular Reactor, and shifted to the basic design phase, in line with its objective to achieve First Nuclear Concrete in 2030 for its reference plant in France.

In July 2023, EDF announced a substantial improvement of its financial performance, a stabilization of its net financial debt and a gradual return to better nuclear fleet availability, allowing to aim at a nuclear output in France between 315 and 345 TWh for 2024 and between 335 and 365 TWh for 2025.

Regarding mining, Orano signed in May a global Partnership Agreement with the Niger government, framing the Orano's uranium mining activities in Niger for the long-term. Following the political events in Niger in July, the Somair mining operations continued, while in September the processing plant was put under maintenance. Orano signed in October a Protocol for the development and operation of the Zuuvch Ovoo uranium mine in Mongolia. Katco's industrial development of the South Tortkuduk uranium mining site in Kazakhstan is progressing according to forecasts. The first processing zone should be connected in 2024.

Regarding conversion, production reached more than 10,000 tU, compared to 8,900 tU in 2022.

Regarding enrichment, in October, Orano's Board of Director has approved a project for more than 30% capacity increase at the GBII enrichment facility. Production will start in 2028, for a yearly 10 M-SWU nominal total production in 2030.

Through a U.S. DOE's RFI (Request For Information), Orano proposed its know-how & experience to create an efficient HALEU fuel supply chain, in support of Advanced Reactor development.

Orano launched in September the development of the 30B-X cylinder for LEU + HALEU fuel transport.

A technical cooperation agreement was signed in May with Japanese utilities for used MOX fuel reprocessing by Orano.

Germany

In April, the three NPPs – Emsland, Isar 2 and Neckarwestheim II – ceased generating electricity and were taken off the grid, according to the amended Atomic Energy Act. This marked the end of nuclear power use for electricity production in Germany, leaving only research reactors operational. Research institutes and industrial facilities continue to be active in the area of nuclear applications and technology.

In October, an IAEA follow-up IRRS mission to Germany was conducted, confirming that all recommendations given in 2019 had been implemented, as well as all but 2 of 25 suggestions issued in 2019. The country was encouraged to continue its efforts to address the remaining topics for continuous improvement. This completed the second cycle of the peer review process, which is mandatory within the EU every ten years.

Greece

In May, the 13 remaining fresh, low-enriched uranium (LEU) fuel elements from the country's only research reactor GRR-1 (which ceased operation in 2004 and is currently licensed for extended shutdown) were exported to Canada to be used by the McMaster University research reactor.

In addition, the Department of Nuclear Engineering of the School of Mechanical Engineering of the National Technical University of Athens also completed the necessary procedures for the export of fresh natural uranium that existed in an out-of-use (dismantled) assembly.

In September, the IAEA conducted an ARTEMIS review mission to Greece, concluding that the country had established a good basis to ensure and increase the safety of radioactive waste management. Nevertheless, the review mission also recognised that there were some areas requiring additional efforts, such as improving stakeholder involvement and securing enough skilled workers for the safe management of radioactive waste.

Hungary

The Paks NPP operator notified the EU in 2023 of its intention to extend the operating lifetime of the four Paks units from 50 to 70 years.

In April, after approval from the European Commission, Hungarian and Russian representatives signed amendments to the EPC (engineering, construction and procurement) contract for the Paks II project. Large-scale site-preparation works continued during the year, with 1.5 million cubic metres of soil excavated, construction of the cut-off wall finished, and the soil-consolidation works started.

In the area of nuclear-fuel diversification and security of fuel supply, the Hungarian Ministry of Energy signed a Memorandum of Understanding with Framatome of France on establishing a 'strategic nuclear relationship', which could enable the use of French fuel in the Paks NPP in the future.

Italy

In September 2023, the Ministry of the Environment and Energy Security (MASE) – in line with government policy and the strategy indicated in the proposal to update the national plan for energy and climate – launched the National Platform for Sustainable Nuclear Energy. The objective of the Platform is to identify a path for potentially reintroducing nuclear energy in Italy, using new sustainable nuclear technologies that are currently being developed. The Platform serves as a point of synthesis and national convergence to discuss initiatives, experiences, concerns, prospects, and expectations related to the advanced nuclear sector, with a focus on sustainability and the contribution that nuclear power could make to decarbonisation.

On decommissioning, the State-owned company Società Gestione Impianti Nucleari SpA (Sogin) announced that it had successfully finished manufacturing two transport and storage metallic casks for the management of U-Th spent nuclear fuel. The two casks are of the TN24ER type and will be used to put in dry storage the U-Th spent nuclear fuel burned in the Elk-River reactor stored in Italy since the late 1960s.

The IAEA's ARTEMIS review mission in October stated that Italy is committed to addressing the challenges of safe management of radioactive waste, while identifying areas for additional efforts, including the need to swiftly approve plans for a national repository for spent fuel and radioactive waste.

Lithuania

In the beginning of the year, Ignalina NPP (Visaginas municipality) signed two contracts for design services for reactor-dismantling technologies with a consortium led by Westinghouse Electric Spain and a consortium led by the French company EDF. Fissile materials were removed from both units of the Ignalina NPP, and the spent fuel is now stored in dry storage facilities.

In April, the State Nuclear Power Safety Inspectorate gave its final approval to the site-safety assessment report on the project to transform the Ignalina NPP bituminised waste storage facility into a surface repository. An environmental impact assessment report on this project is under preparation.

In November, the second waste-disposal campaign was completed in the Ignalina NPP Landfill Disposal Facility for short-lived, very low-level waste, completing the 'hot trial' at the site.

In 2023, 77 'most suitable' locations were selected for further research for their potential as deep geological repository (DGR) sites.

In July, an IAEA ARTEMIS mission was carried out to review the country's DGR project. The review provided 8 recommendations, and 6 suggestions and highlighted 1 good practice.

Netherlands

The government is taking the necessary steps to construct two NPPs – each with a capacity of >1 000 MW and is now working towards a provisional choice of site and the start of the tender process. Currently, three technology suppliers are carrying out a technical feasibility study and a market consultation. Work to extend the operating life of the Borssele NPP is ongoing.

In February, the Dutch Authority for Nuclear Safety and Radiation Protection (ANVS) granted a licence under the Nuclear Energy Act for the construction of the PALLAS-reactor. This is a new medical isotopes reactor that will replace the old High Flux Reactor (HFR) in Petten. Preliminary work subsequently started on building the construction pit and foundation for the reactor. The PALLAS reactor has been fully funded by the government.

An additional amount of EUR 65 million was allocated in 2023 to accelerate the development of SMRs in the Netherlands, with a specific focus on the Dutch manufacturing industry. The aim of this programme is to anticipate the possible installation of SMRs in the Netherlands by first exploring the need for and potential usefulness of SMRs in the Dutch energy mix, based on an analysis of local demand.

In December, Urenco Netherlands announced a 15% increase in enrichment capacity at the Almelo site where it enriches uranium.

In November 2023, two IAEA review missions – IRRS in June and ARTEMIS in November – conducted review missions in the Netherlands. The missions comprehensively evaluated the Dutch legal and governmental framework and regulatory infrastructure for both nuclear safety and waste management. The IRRS team concluded that the country had demonstrated its commitment to continuous improvement in nuclear and radiation safety, while advising the Netherlands to ensure it had sufficient regulations and resources in place to regulate its future facilities and activities. The ARTEMIS team also confirmed that the country's government and regulatory bodies are committed to safety, innovation and openness.

Poland

In 2023, Poland made progress on its project to build the country's first NPP. This progress included: (i) the basic decision to build the NPP; (ii) a decision on environmental conditions for the NPP; (iii) a location decision to build the facility in Lubiatowo-Kopalino in Choczewo, Pomerania; and (iv) the signing of an engineering services contract between Polskie Elektrownie (PEJ) and the Westinghouse-Bechtel consortium.

A programme to modernise the MARIA research reactor located outside Warsaw was launched in 2023 and will be finalised by 2027. The aim is to strengthen this research reactor and ensure it operates safely until at least 2050.

An IAEA IRRS mission was conducted in Poland in September to review the country's governmental, legal and regulatory framework for nuclear and radiation safety. The mission found that Poland's nuclear regulatory system was suitable and prepared for launching the country's nuclear programme. Three good practices were identified by the mission, although the mission also found a main challenge: ensuring the independence of – and sufficient resources for – Poland's regulatory body.

Portugal

Portugal does not operate any NPPs, but it does generate radioactive waste through medical, industrial and research applications. All nuclear fuel from the research reactor Reactor Português de Investigação (RPI), which ceased operation in 2016, has been transported back to the US for disposal as part of a US-Portuguese bilateral agreement, and Portugal no longer possesses any nuclear fuel or spent fuel. The RPI is currently undergoing a transition towards decommissioning.

An IAEA ARTEMIS review mission team concluded that Portugal is committed to ensuring the safe and effective management of radioactive waste. It also identified a need to develop Portugal's national radioactive waste-management programme, and the country was advised to allocate sufficient resources for the implementation of this programme.

Romania

The project to refurbish Unit 1 of the Cernavodă NPP is now in its second phase. This phase involves: (i) securing the financial resources for the implementation of the project; and (ii) preparing to begin the activities identified in Phase I. In November, SN Nuclearelectrica SA entered into a contract with CANDU Energy and Canadian Commercial Corporation for the supply of reactor tools, reactor components, and engineering/technology services.

SN Nuclearelectrica SA concluded an engineering services contract with CANDU Energy for the re-assessment of structures, incorporating project improvements from a nuclear-safety perspective. These services will be supplied to the Cernavodă NPP Units 3 and 4.

The Doicesti SMR project is in the transition phase from the FEED 1 study to the FEED 2 study. Phase 2 of the FEED study consists of: (i) detailed site-characterisation activities; (ii) permitting activities; (iii) licensing and regulatory activities; (iv) detailed project schedule development; (v) budget planning for project execution; and (vi) preparation for the procurement of long-cycle manufacturing materials.

Between January and March 2023, all the necessary steps were taken to authorise the production process and prepare the facilities for the start of uranium concentrate processing, effectively to operationalise a uranium enrichment facility at Feldioara. Currently, the Feldioara site operates as a subsidiary of SNN, a state-owned nuclear-energy company, and is operating at optimal capacity.

In June, SNN signed an EPC contract to complete the first tritium disposal plant with Korea Hydro & Nuclear Power (KHNP). The facility will increase the radiological safety of the Cernavodă NPP and further reduce the volume of radioactive waste produced at Cernavodă.

In November, the IAEA concluded its IRRS mission to Romania, confirming the country's commitment to maintaining and strengthening its regulatory framework for nuclear and radiation safety. The Romanian authorities were complimented on their preparations for the future development of SMRs, while recommendations were given to improve coordination between government agencies involved in radiation-source facilities and activities.

Slovakia

In 2023, the third unit of the Mochovce NPP was fully commissioned. Currently, there are 5 units in operation at Mochovce (all of the VVER 440 type). The fourth unit in Mochovce is in the process of completion, with start-up expected in 2025.

Mochovce November 2023

©Euratom Supply Agency

In line with the ESA's diversification policy, Slovenské elektrárne, a Slovakian electricity utility, signed a memorandum of understanding with Framatome of France in May and a contract with Westinghouse in August to supply nuclear fuel for VVER 440 units.

As part of its preparations for a new NPP project (up to 1 200 MW), company JESS submitted a siting licence application for the location of its New Nuclear Source Project in Jaslovské Bohunice.

As part of the work to decommission the NPP V1 in Jaslovské Bohunice, the key dismantling project 'Dismantling of Reactor Coolant System Large Components' continued to make good progress in 2023, with decontamination of the fragmentation and decontamination facilities. A total of 3 492 tonnes of processed contaminated material could be freely released, representing 98.9% of processed metallic material.

In 2023, Slovakia was selected for the Project Phoenix initiative, a US initiative to explore the possibilities of implementing SMR technology. Slovakia has selected five locations that will be considered as potential locations for the construction of an SMR.

In February, an IAEA ARTEMIS review mission was carried out in Slovakia. The results of the mission confirmed that the country is committed to the safe management of radioactive waste and spent fuel, while noting opportunities to increase preparations for geological disposal.

Slovenia

In 2023, the government adopted a strategy to phase out coal for electricity production by 2033 and to continue to rely on the existing Krško NPP, co-owned 50/50 with Croatia.

In January, an environmental permit was approved to extend the life of the existing Krško NPP from 40 to 60 years. With this the decision, the lifetime extension of the Krško NPP and its operation until 2043 became approved and valid.

Planning for the future of a potential second unit at the NPP Krško (Krško 2) was initiated in 2019, during the preparation of Slovenia's national energy and climate plan. More recently, this planning is converging towards a decision to start the planning process to build one or more units as part of a new Krško 2 with a power range up to 2 400 MWe. In November, the Ministry of Environment, Climate, and Energy presented a long-term energy supply proposal providing a comprehensive framework for the long-term use of nuclear energy in Slovenia, including plans to guide construction of the proposed new Unit 2 at the Krško NPP.

Spain

In December, the Council of Ministers approved the 7th General Radioactive Waste Plan (GRWP) – a document setting out: (i) a strategy for nuclear-waste management; (ii) activities which must be carried out to ensure the safe management of the spent fuel and radioactive waste; (iii) activities which must be carried out to decommission certain facilities; and (iv) economic and financial analyses linked to these activities.

The 7th GRWP – adapted to Council Directive 2011/70/Euratom – sets out the main future milestones for the management of spent fuel and radioactive waste in Spain, as well as the activities that the country will need to undertake in the coming years. It is consistent with both: (i) the evolution of the country's electricity mix planned in the national integrated energy and climate plan; and (ii) the protocol for the orderly shutdown of nuclear power plants (2027-2035), signed in March 2019 between Enresa (the Spanish state-owned company responsible for managing the spent fuel and the radioactive waste as well as for the decommissioning of facilities) and the owners of the NPPs.

A lengthy process, which began in 2020, was required to approve the 7th GRWP. As part of this process, the GRWP was for the first time subjected to a strategic environmental assessment, including public consultation, and to a report from the Nuclear Safety Council and Spain's Autonomous Communities.

In July, Enresa became, by Ministerial Order, the licence holder of the Santa María de Garoña NPP, which ceased operations in December 2012 so it could start to be decommissioned.

The decommissioning strategy for the Santa María de Garoña NPP is composed of two phases.

Phase 1 includes: (i) the removal of spent fuel from the pool and its subsequent safe storage in a temporary facility located on-site; (ii) the modification of the turbine building; (iii) initial radiological characterisation campaigns; (iv) decontamination of systems; and (v) the dismantling of conventional installations.

Phase 2 involves the dismantling of facilities, systems, and buildings.

Sweden

In 2023, the Swedish government adopted a roadmap to put in place the necessary conditions for new nuclear energy production, with an aim to install capacity equivalent to at least 2 large-scale reactors by 2035 and 10 large-scale reactors by 2045. To create favourable conditions for investment, the government also initiated inquiries on: (i) how to put in place a more efficient permitting procedure; (ii) a new financing and risk-sharing model; and (iii) the future shape of the electricity market. Credit guarantees will also be introduced, and legislation has been revised to remove the limit on the number of reactors in the country or restricting nuclear power only to existing sites.

Sweden also conducted studies in 2023 to examine the feasibility of extending the life of its six operating NPPs to up to 80 years.

Sweden's radioactive waste-management company applied to the Swedish Radiation Safety Authority in 2023 to extend the capacity of the existing final repository for low- and intermediate-level waste at Forsmark to almost three times its current size so that it can receive demolition waste from decommissioned Swedish NPPs.

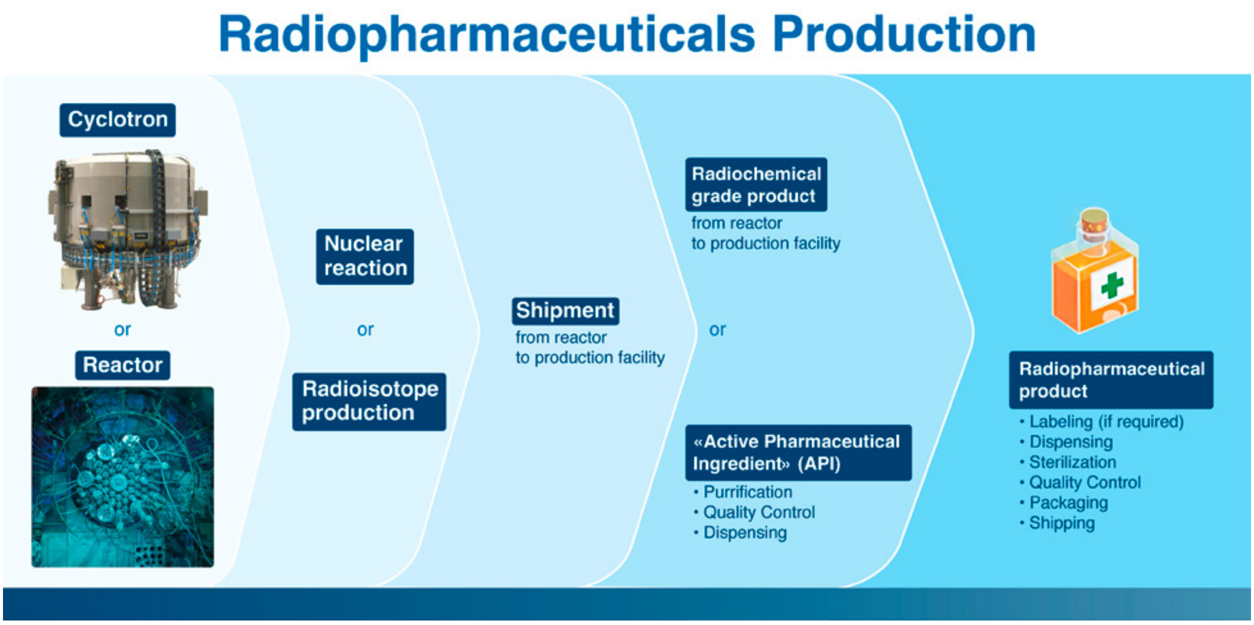
Several initiatives and cooperations were launched in 2023 to investigate the deployment of new nuclear power plants in Sweden, including LSRs, SMRs and Generation IV reactors.

An IAEA ARTEMIS mission was carried out in Sweden in April. The review team concluded that the country has a comprehensive, robust and well-functioning system for the safe management of radioactive waste and spent fuel from nuclear power plants. The ARTEMIS team gave some advice on how to improve Sweden's policies and strategies for radioactive waste from other sources, e.g. industrial, research or medical applications.

3.3. Non-power applications of nuclear technology: Supply of medical radioisotopes

Medical radioisotopes play a vital role in medicine, serving both diagnostic and therapeutic purposes. They are instrumental in identifying and addressing severe illnesses such as cancer, cardiovascular conditions, and neurological disorders. Around the world, over 10 000 hospitals rely on approximately 100 distinct nuclear-medicine procedures, conducting close to 49 million medical interventions annually. In the EU, more than 1 500 nuclear-medicine facilities treat roughly 10 million patients each year.

In the fight against cancer, nuclear medicine is a crucial ally, with approximately 60% of nuclear-medicine procedures dedicated to oncology. Moreover, the use of medical radioisotopes in cancer treatment is rapidly evolving, with the anticipation of significant growth in the market for innovative radiopharmaceuticals in the coming years.



©Nuclear Medicine Europe

Around the world, over 10 000 hospitals rely on approximately 100 distinct nuclear-medicine procedures, conducting close to 49 million medical interventions annually. In the EU, more than 1 500 nuclear-medicine facilities treat roughly 10 million patients each year.

Nuclear research reactors are the principal source of radioisotopes, although alternative non-fission technologies like cyclotrons and accelerators are also being used and further developed for this purpose. The production of radioisotopes entails complex and highly specialised supply chains, often spanning many countries and continents, necessitating continuous, just-in-time delivery operations.

Technetium-99m (Tc-99m) is the most prevalent radioisotope, employed in 80% of nuclear-medicine diagnostic procedures globally. Its production involves a multi-step process, commencing with the irradiation of uranium targets in nuclear research reactors to yield Molybdenum-99 (Mo-99). The Mo-99 is then extracted from the targets in specialised processing facilities and used to make Tc-99m generators, which are then dispatched to hospitals for medical procedures. Any disruption to this challenging supply chain could lead to significant consequences for patients.

The EU plays a pivotal role in the nuclear-medicine sector, hosting a comprehensive supply-chain network comprising:

- 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 target-processing facilities: Curium in the Netherlands and IRE in Belgium;
- manufacturing sites for key Tc-99m generators in the Netherlands, France, and Poland.

Accounting for over 60% of the global market share for Mo-99/Tc-99m, the EU has been instrumental in many significant advances in nuclear medicine, encompassing both pharmaceutical and clinical advances.

For insights into the security of the supply chain for medical radioisotopes, please refer to Chapter 2.1.

3.3.1. Reactor scheduling and monitoring the supply of Mo-99

The Security of Supply Working Group, established by Nuclear Medicine Europe (NMEU), provides information to the European Observatory on the Supply of the Medical Radioisotopes (please see Chapter 5.2.4). [42] The Security of Supply Working Group collaborates closely with stakeholders throughout the supply chain to coordinate reactor maintenance schedules, thus preventing and mitigating disruptions in the supply of Mo-99/Tc-99m. The Emergency Response Team (ERT), operating under the Working Group, includes representatives from research reactors, Mo-99 processors, and Mo-99/Tc-99m generator manufacturers. The ERT is responsible for monitoring production and supply issues to detect any potential shortages of Mo-99 and mitigate any possible negative consequences of these shortages. The vigilant monitoring and coordination efforts of the ERT are indispensable for upholding the Mo-99/Tc-99m supply chain and ensuring uninterrupted access to these crucial radioisotopes for medical facilities worldwide.

In 2023, the Security of Supply Working Group dealt with several significant events, which had short-term negative impacts on supply. One of these events was the delayed return to service of the MARIA research reactor in Poland. Due to prolonged maintenance works, the reactor could not resume operations as planned in March 2023, and eventually restarted only in October. The group also addressed two instances of delayed

XIX Plenary meeting of the European Observatory on the Supply of Medical Radioisotopes

© Nuclear Medicine Europe

42 Nuclear Medicine Europe - Security of Supply: https://nuclearmedicineeurope.eu/security-of-supply/

restarts of the HFR research reactor in the Netherlands. The causes for the delays were: (i) the detection in May of increased water leakage from the reactor pool, collected in designated tanks; and (ii) repairs in August-September due to a defect in one of the heat exchangers.

In September, the ERT dealt with the delay in operations of the SAFARI research reactor in South Africa, which encountered technical issues following its restart from planned maintenance.

The NMEU's ERT played a pivotal role in managing these supply-disruption challenges. The Joint Communication Team, set up in collaboration with the Observatory, disseminated the updates received from the ERT to various stakeholder groups, including European Commission departments, the EU Health Security Committee, the Council of the European Union (Atomic Questions Group), the European Medicines Agency, the European Association of Nuclear Medicine, the OECD/NEA and the IAEA.

3.3.2. SAMIRA

In the field of non-power applications of nuclear and radiation technology, the Commission has continued to implement the SAMIRA action[43] plan in the three priority areas of the plan: securing the supply of medical radioisotopes; improving radiation quality and safety in medicine; and facilitating innovation and the technological development of medical ionising radiation applications. Three areas in which the Commission made significant progress on the SAMIRA action plan in 2023 are set out in the bullet points below.

- A high-level workshop on the supply of medical radioisotopes was held in April 2023. The workshop, opened by Commissioner Simson, was attended by representatives of several Member State ministries, the US Department of Energy and numerous other stakeholders. This was followed by the launch of the ERVI feasibility study to assess potential ways to maintain and improve the supply of medical radioisotopes. The ERVI work is supported by a steering group consisting of key stakeholders and Member States.

- To improve quality and safety, several activities are being implemented as part of the comprehensive work programme of the Steering Group on Quality and Safety (SGQS), which consists of Member States' radiation and health authorities. These activities are implemented in close coordination with DG SANTE and other Commission DGs and receive significant support from the EU4Health programme. Stakeholder workshops were held in 2023 for several projects covering diverse areas (such as justification of computed tomography imaging, patient radiation monitoring, and regulation for therapeutic nuclear medicine). These projects should be completed in 2024. Furthermore, the SGQS adopted a position paper on the clinical audit of medical radiological procedures.

- In the innovation area, a strategic research agenda and roadmap for medical applications of ionising radiation was delivered. These documents should serve as a basis for building synergies between the Euratom research programmes, Digital Europe, and the health topic under Horizon Europe.

> The Commission has made significant progress in implementing the SAMIRA action plan.

3.3.3. Studies and research

Nuclear safety of research reactors

In 2022, the European Commission launched a study to: (i) collect information on the status of safety assurance in research reactors; (ii) assess safety requirements for research reactors; and (iii) assess current practice in the safety assurance of research reactors. The study focused in particular on systematic re-assessment processes via the periodic safety reviews as well as the ageing management activities, in particular reflecting the conclusions of first topical peer reviews. The project final report was published in 2023. [44] The study contributes to an understanding of how well aligned research reactors in the EU Member States are with the Nuclear Safety Directive. As part of the study, national regulations applicable to research reactors were benchmarked, as was the application of these regulations by operators. Areas for possible improvement were also identified. The findings of the study were presented and discussed during a workshop, which was attended by regulators and operators of research reactors. Recommendations to improve the safe and sustainable operation of research reactors were proposed in areas such as: (i) the use of a graded approach; (ii) safety assessment; (iii) design extension conditions; [45] (iv) how to manage ageing reactors; and (v) long-term strategy.

43 SAMIRA Action Plan - https://energy.ec.europa.eu/topics/nuclear-energy/radiological-and-nuclear-technology-health/samira-action-plan_en
44 Safe, Sustainable Operation of Research Reactor Facilities in the EU: https://op.europa.eu/en/publication-detail/-/publication/55eefc7d-926d-11ee-8aa6-01aa75ed71a1/language-en
45 The term "design extension conditions" is used to describe those accidents, beyond the design basis, for which additional prevention and mitigation provisions are required.

Conversion of high-performance research reactors

Building on the outcome of the Heracles-CP [46] and LEU-FOREvER [47] projects, the EU-Qualify [48] project continued in 2023. Coordinated by the Belgian Nuclear Research Centre (SCK-CEN) and involving five partners, the project focused on the qualification of three particular types of fuels: (i) the dispersed U-Mo fuels; (ii) the monolithic U-Mo fuels; and (iii) the high-loaded dispersed U_3Si_2 fuels. This qualification was accomplished through: (i) fabrication and concurrent qualification of pilot manufacturing equipment and processes; (ii) irradiation under representative irradiation conditions; (iii) post-irradiation examinations; and (iv) modelling of the in-pile behaviour to support LEU conversion safety analyses. On the basis of the data, the project aims to: (i) investigate the future needs of each EU research reactor type in terms of volume and fuel-design requirements; and (ii) prepare technical requirements for the safety of manufacturing, storage, transport and reprocessing of this research reactor fuel.

The 2023-2025 Euratom research and training work programme, published in 2023, included a research call (with an EU contribution of EUR 7 million) allowing for a continuation of the work initiated by the three projects [49] above.

PRISMAP

The key objective of the PRISMAP [50] project (2021-2025) is to federate key infrastructures to set up a common entry point to this European network for biomedical researchers and physicians. PRISMAP provides a sustainable supply of high-purity-grade research radionuclides for medicine, thus speeding up the introduction of new medical radioisotopes. The PRISMAP network groups together 23 European academic institutions and research centres. PRISMAP also brings together a set of key large European, national and regional production infrastructures, chosen specifically for their expertise in the production and dispatch of non-conventional radionuclides. Their integration in a joint network makes it possible to provide research radionuclides and reach new purity grades for medical research. The network also comprises research centres and hospitals which all possess key skills in translational research and are crucial to fostering a new research era based on emerging medical radionuclides. The PRISMAP network can also develop services or host users that lack proper licences, infrastructures or specific expertise. In addition, research projects submitted to PRISMAP can be developed either through the investigation of these research medical radionuclides across Europe or directly in the biomedical PRISMAP hubs. Importantly, as the community of PRISMAP researchers grows and strengthens in the coming years, it will become possible to include new translational research centres and production facilities in the PRISMAP network. These new centres and facilities will be able to pool their knowledge, expertise and infrastructure with the existing PRISMAP partners to provide a sustainable source of high-purity-grade novel radionuclides for medical research. In 2023, following the evaluation of the first calls, PRISMAP entered a new phase with the first radionuclides being delivered, and a first scientific publication in the Journal of Nuclear Medicine on preliminary results obtained in one of the 23 approved projects. Recently, the PRISMAP information portal was launched. This portal gathers documents providing information on: (i) the radionuclides offered; (ii) specifications; and (iii) standard practices and regulations relevant for the major fields/topics addressed by PRISMAP (i.e. on nuclear decay data, the production of radionuclides, the development and preparation of radiopharmaceuticals, specifications and quality control/metrology and radioprotection/transport issues).

TOURR

The TOURR project (Towards Optimised Use of Research Reactors in Europe) [51] was completed in 2023. It was a coordination action lasting 3 years, financed under the Euratom programme. The project encompassed several key objectives aimed at improving the European research reactor landscape. It developed a strategy for the optimised use of the European research reactor fleet and prepared the ground for the implementation of this strategy. The objectives included: (i) assessing the current status of the European research reactor fleet, including plans for upgrades; (ii) evaluating urgent EU requirements; (iii) developing tools to implement the optimised use of research reactors; and (iv) increasing awareness among decision-makers about the future role of these reactors. Within this framework, the primary ambition of the TOURR project was to ensure access to – and the availability of – research reactors as integral components of the European Research Area [52] while providing support for the consistent supply of medical radioisotopes. Among the notable deliverables [53] of the project were:

- the formulation of a strategic framework for the optimised use of research reactors throughout Europe;
- setting up a comprehensive database detailing the European research reactor fleet and its planned use in the period 2030-2050;

46 HERACLES CP: Towards the Conversion of High-Performance Research Reactors in Europe: https://cordis.europa.eu/project/id/661935
47 Low Enriched Uranium Fuels fOR REsEarch Reactors: https://cordis.europa.eu/project/id/754378
48 'European QUalification Approach for Low Enriched Fuel Systems for secure production supply of medical isotopes: https://cordis.europa.eu/project/id/945009
49 EU Funding & Tenders Portal (europa.eu): https://cordis.europa.eu/project/id/101008571
50 The European medical isotope programme: Production of high purity isotopes by mass separation: https://cordis.europa.eu/project/id/101008571.
51 TOURR (Towards Optimized Use of Research Reactors in Europe): https://www.tourr.eu/.
52 ERA (European Research Area): https://research-and-innovation.ec.europa.eu/strategy/strategy-2020-2024/our-digital-future/european-research-area_en
53 CORDIS – EU research results: https://cordis.europa.eu/project/id/945269/results.

- the creation of an online platform dedicated to facilitating the optimised use of research reactors across Europe;
- the formulation of recommendations for planning the refurbishment of existing research reactors or constructing new ones.

SECURE

In 2023, work continued on the 'Strengthening the European Chain of sUpply for next-generation medical RadionuclidEs' (SECURE) [54] project, which began in 2022. The ambition of the SECURE consortium is to identify and use efficiently the current resources for new radionuclides, particularly for alpha emitters and the relevant beta-emitting theranostic radionuclides. The development of alternative technologies for the production of these therapeutic radionuclides for improved patient treatment requires multidisciplinary scientific and technological knowledge. Radioisotopes that are critical for the success of nuclear medicine were selected. Research activities addressed some of the major challenges to securing the future availability of these radioisotopes by removing critical barriers to sustainable production and developing guidance and recommendations for exploring the full clinical potential and safe application of radioisotopes. In 2023, the first milestones related to the alpha emitters were reached, and the first deliverables were provided paving the way for further developments.

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

Stable isotopes

In October 2023, the French nuclear-fuel-cycle company Orano inaugurated its new Jean Fourniols Stable Isotopes Laboratory at its Tricastin site in France. Construction of the laboratory began in March 2021, with civil engineering works completed in October 2022. The first centrifuges were commissioned with a first production run of isotopic elements (xenon). Stable isotopes are non-radioactive forms of atoms. They are used for many applications and demand for them continues to grow. They are used in particular in the medical sector (cancer diagnosis and treatment), in the industrial sector and in basic research.

Lutetium-177

In April, Eckert & Ziegler Radiopharma GmbH, a subsidiary of Eckert & Ziegler Strahlen-und-Medizintechnik AG, received a manufacturing authorisation for Lutetium-177 (non-carrier-added Lu-177) in Good Manufacturing Practices (GMP) grade from the competent German authority. The approval was the basis for the marketing authorisation of Lu-177 as a drug, but also for use of this radioisotope as a starting material for the manufacture of radiopharmaceuticals.

In May, Isotope Technologies Munich SE (ITM) announced the opening of its new production facility, NOVA,for therapeutic radionuclides in Neufahrn near Munich. ITM's new facility is the world's largest production site for Lu-177. Due to its medical properties, Lu-177 has become more important in recent years in precision oncology treatments as a valuable starting material for the production of various radiotherapeutics. Once ITM's new NOVA production facility is fully operational, ITM will increase by tenfold its capacity to supply clinics, pharmaceutical partners, and its own drug pipeline. The development and production of medical radioisotopes by ITM was enabled, in part, by years of collaboration with the Garching Research Reactor (FRM II) and the Technical University of Munich. ITM will operate the new production site at NOVA Neufahrn industrial park in addition to its existing manufacturing facility IAZ at the main site in Garching near Munich.

In November, Romania's Nuclearelectrica and France's Framatome signed a cooperation agreement on exploring production of the medical isotope Lutetium-177 (Lu-177) at the Cernavodă nuclear power plant. Under the agreement, a technical feasibility study will be conducted, based on Framatome's work on isotope production in Canada. The agreement will look at how to 'maximise the existing infrastructure to convert targets into medical isotopes'. Framatome Healthcare, through its Isogen joint venture with Canada's Kinectrics, was involved in 2022 in an international collaboration with Bruce Power and ITM to produce Lu-177

Orano Stable Isotopes Laboratory

©Orano, CRESPEAU CYRIL

54 SECURE Project (Strengthening the European Chain of sUpply for next generation medical RadionuclidEs): https://enen.eu/index.php/portfolio/secure-project/

from a commercial nuclear power reactor for the first time, at Bruce Power's Unit 7. Like Cernavodă, Bruce Power's Unit 7 is a CANDU pressurised heavy-water reactor.

In December, Framatome and Global Morpho Pharma announced plans to work together on the development of high-capacity technology for the purification of medical radioisotope non-carrier-added Lu-177. Global Morpho Pharma has developed a patented technology to separate Lu-177 from Ytterbium-176 (Yb-176) targets, with capacities up to 50 times greater than possible with existing technologies. Under an announced services agreement, Framatome will provide its laboratory expertise and services to validate the pilot equipment at industrial scale at its technical centre in Erlangen, Germany.

Actinium-225

In May, the US-based company SpectronRx announced that it will open its first European radio-labelling facility for medical radioisotopes. This facility will be built on the premises of the Belgian Nuclear Research Centre (SCK-CEN) in Mol, Belgium. It will be operational in 2024 and will focus on Actinium-225 (Ac-225). This promising therapeutic radioisotope shows great potential in the treatment of cancer. Both organisations made their cooperation official by signing a memorandum of understanding (MoU). In the MoU, it is agreed that SpectronRx will provide state-of-the-art equipment and a quality system with GMP-qualified procedures, while SCK-CEN will supply the necessary resources to meet the development objectives.

In June, TerraPower Isotopes and PanTera, the Belgian joint venture created by SCK-CEN and IBA, announced that they had signed a strategic collaboration to increase the global availability of Ac-225. The companies will work together to increase near-term production of Ac-225 to support ongoing clinical trials and ensure the large-scale supply of the radioisotope in the long term, addressing growing global demand. Under this collaboration, both companies will use TerraPower Isotopes' natural-decay method based on Thorium-229 (Th-229) and PanTera's 'Gamma route' (based on Rhodotron and Radium-226) to produce Ac-225.

In October, ITM and Canadian Nuclear Laboratories (CNL) announced the launch of Actineer Inc., a new joint-venture company between CNL and ITM for the industrial-scale production of Ac-225. Under the terms of their joint-venture agreement, Actineer will advance Ac-225 production and processing technologies to set up short-term production capabilities for the medical isotope that will boost international supplies, while working long-term towards the construction of a new actinium production facility (APF) that will feature dedicated large-scale infrastructure to produce Ac-225. The collaboration also encompasses the development and implementation of the manufacturing process to be used at the APF. CNL will provide the starting material for irradiation and initially manage the production process during the interim scale of radiochemical grade Ac-225 supply, while ITM will further process the resulting Ac-225 to pharmaceutical grade under GMP specifications. ITM will also be responsible for global marketing, sales, and distribution.

Terbium-161

In April, ITM announced that it had entered into a co-development and exclusive licence agreement with the Paul Scherrer Institute (PSI), a leading Swiss research institute in the natural and engineering sciences, for manufacturing a novel therapeutic radionuclide, Terbium-161 (Tb-161). The partners will combine their respective technologies and expertise in the production of Tb-161, including clinical and commercial use in targeted radionuclide therapy for the treatment of cancer.

IBA cyclotron in Poland

In December, IBA (Ion Beam Applications SA) announced that it had started to install a Cyclone 30 XP in Poland. The completion of rigging in the POLATOM site in Poland follows the successful commissioning of the first Cyclone 30 XP machine in Jülich, Germany, earlier in 2023. An IBA cyclotron Cyclone®70 XP, installed in France in 2008, has already enabled multiple research programmes. IBA and these three sites (ARRONAX (France), Forschungszentrum Jülich (Germany), and POLATOM (Poland)) are active participants in the European Cooperation in Science and Technology Action: Network for Optimised Astatine-211 (At-211) labelled Radiopharmaceuticals (NOAR). This collaborative effort showcases a commitment to overcoming challenges and advancing targeted research in alpha therapy. Despite its scarcity, At-211, an alpha emitter, is used in clinical research for targeted alpha-therapies in the field of oncology to treat brain, thyroid, ovarian, breast, and prostate cancer.

Delivery of IBA Cyclone 30XP cyclotron to the Radioisotope Centre POLATOM, National Centre for Nuclear Research in Poland

Production of medical radioisotopes in CANDU reactors

In September, Laurentis Energy Partners (LEP), a subsidiary of Ontario Power Generation (OPG) announced that it will collaborate with Romania's nuclear energy utility, S.N. Nuclearelectricia SA (SNN): (i) on the production of medical isotopes at the Cernavodă NPP; and (ii) to explore the possibility of heavy-water production in Romania. The announcement follows an announcement by Canada's Natural Resources and Energy Minister of $3 billion CAD in export financing for Romania's Cernavodă NPP to support clean-energy security. The MoU enables SNN and LEP to work together on opportunities in a number of areas, including isotope production at SNN's Canada Deuterium Uranium (CANDU) reactor units. Laurentis and its parent company, OPG, are recognised leaders in nuclear isotopes, produced through CANDU reactors at the Darlington and Pickering nuclear power stations.

PALLAS

In January, the Foundation Preparation Pallas-reactor (PALLAS) [55] in the Netherlands launched the pre-qualification for the general contractor to build the PALLAS-reactor, including several buildings and ancillary facilities under EU procurement guidelines. Prior to the launch of this pre-qualification, the basic design activities for the PALLAS-project were completed in collaboration with ICHOS, a Dutch-Argentinian consortium contracted for the design activities. In December, PALLAS chose FCC Construcción (FCC) as the contractor for constructing the PALLAS-reactor. Following the tender procedure, the contract was signed with FCC. The company is part of the FCC Group, internationally recognised for its environmental, water and construction services. FCC activity covers all areas of engineering and construction, both residential and non-residential.

In February, the Nuclear and Radiation Protection Authority (ANVS) of the Netherlands granted the Nuclear Energy Act licence for the construction of the PALLAS-reactor, which came into effect in April. The Ministry of Infrastructure and Water Management (Rijkswaterstaat) also issued the Water Act permit for the intake and discharge of cooling water. With these permits coming into effect, the permit under the Environmental Law (General Provisions) Act for the construction of the buildings and cooling water pipes also will come into force.

In March, Tractebel and NRG|PALLAS signed an MoU to cooperate to support the construction of new nuclear power plants in the Netherlands.

In May, work started on the construction pit for the PALLAS-reactor. Using special excavation techniques, so-called diaphragm walls were being put in place into which the concrete will then be poured.

In September, the Dutch Minister of Health, Welfare and Sport announced full financing for the construction of the PALLAS-reactor in the town of Petten in the northern Netherlands. This was a major step towards building the new PALLAS-reactor.

Energy and health campus, Petten (NL)

©NRG PALLAS

FIELD-LAB

In December, the new FIELD-LAB [56] facility in Petten was officially opened. FIELD-LAB aims to help accelerate the development of new nuclear medicines for the treatment of cancer. FIELD-LAB is already involved in several promising projects, such as a pilot study to use radioactive cisplatin for chemotherapy. Other important projects include the development of unique technologies to produce the isotopes Lead-212 and Lutetium-177. Lutetium-177 has long been used to treat neuroendocrine tumours (NETs) and may now also be applied to treat metastatic prostate cancer. Lead-212 is a promising new isotope and is being used in research for more effective therapies for cancer treatment within the FIELD-LAB consortium. Production processes for Lutetium-177 and Lead-212 will be carried out at the FIELD-LAB facility over the coming year. The FIELD-LAB initiative has created a unique partnership between Dutch academic medical centres and dedicated industrial partners. With FIELD-LAB, scientists and other parties gain access to more medical isotopes for research. The FIELD-LAB building uses the extensive nuclear infrastructure at the Energy & Health Campus in Petten. FIELD-LAB was co-funded from the European Union by Kansen voor West programme, and the Province of North Holland.

55 PALLAS: https://www.pallasreactor.com/en.
56 FIELD-LAB: https://www.field-lab.nl/.

IRE conversion

In March, the Institute for Radioelements (IRE) in Belgium announced the complete conversion of its production process to LEU. The IRE thus definitively marked its contribution to the international commitment to put an end to the civil use of highly-enriched uranium for the production of medical isotopes, making it possible to fulfil a Joint Statement issued by the governments of Belgium, France, the Netherlands, and the United States at the 2012 Nuclear Security Summit. The US Department of Energy's National Nuclear Security Administration (DOE/NNSA) provided financial and technical support for the conversion. This complete conversion to an LEU process was the culmination of years of work and collaboration between the R&D, production, safety, quality assurance and regulatory teams at the IRE to put in place an entirely new industrial process for supplying Mo-99 and I-131 to healthcare professionals, without impacting the site's production capacity. The close cooperation between various actors involved in this endeavour made it possible to advance the goals of both: (i) nuclear security; and (ii) the security of supply of the most vital medical radioisotopes.

RECUMO facility

In February, a ground-breaking ceremony was held in Mol in Belgium to mark the start of construction of the RECUMO [(57)] facility, which is scheduled to begin operating in 2026. The project is a continuation of the long-standing partnership between SCK-CEN and its sister company, the IRE. In this new facility, the nuclear research centre will convert radioactive residues resulting from the production of medical radioisotopes into LEU and purify these residues. The high-quality material that is recovered can be reused as fuel for research reactors or as targets for radioisotope production. For the purification process, RECUMO uses state-of-the-art radiochemistry technology. This is not the first time that SCK-CEN has made use of this technique. In the 1980s, this technique was already performed in laboratories. The IRE and SCK-CEN have developed, optimised and fine-tuned this technique for the RECUMO project.

Centralised Radiochemical Facility (CRF)

In November, a foundation stone was symbolically laid down for the CRF [(58)] in Mol, Belgium. Construction on the facility has now begun, with commissioning scheduled for 2026. The production facility will focus on Lutetium-177. Starting in 2026, the nuclear research centre SCK-CEN will gradually progress towards producing lutetium for 15 000 patients in the short term and 100 000 patients in the long term. The CRF facility has also been designed to process promising next-generation isotopes which may make it possible for cancers to be treated even more effectively.

JULES HOROWITZ MATERIAL TEST REACTOR (JHR)

In 2023, the JHR [(59)] project in France met major milestones such as: (i) completing factory acceptance tests of the fuel loading machine; and (ii) successful acceptance of the X-ray tomography and gamma spectrometry non-destructive examination (NDE) benches. These benches will make possible the NDE of technological irradiation devices containing experimental samples before and after irradiation in the reactor. This NDE equipment was made as part of an in-kind contract; the CEA and its Finnish partner VTT specified and monitored the design and construction of these two test benches. For 8 years, this project involved a team from the CEA to monitor the design, the manufacture, the assembly and the commissioning tests. This equipment will be tested and used in the TOTEM test facility at the CEA Cadarache site before being installed in the JHR.

2023 also saw significant progress in the development and testing of experimental devices and the completion of pools and hot cells.

The major event for the JHR project in 2023 was the positive outcome following the July 2023 meeting of the French Nuclear Policy Council. Following this meeting, the French government decided to invest in the JHR project, endorsing the roadmap drawn up by the CEA to finalise the construction of the reactor by 2032-2034. This decision reaffirms the key role of the JHR for the extension of the existing nuclear fleet and for the deployment of new nuclear reactors, both NPPs and SMRs. This positive decision from the French Nuclear Policy Council gave a boost to the project. Site construction activities have already accelerated with a focus on electromechanical installation.

57 SCKCEN-RECUMO: https://www.sckcen.be/en/infrastructure/recumo.
58 SCKCEN-CRF: https://www.sckcen.be/en/infrastructure/crf-centralized-radiochemical-facility.
59 RJH Reactor: https://jhrreactor.com/.

4. World market for nuclear fuels in 2023

This chapter presents some of the key developments in 2023 relating to the different stages of the fuel cycle. According to the International Atomic Energy Agency (IAEA), the world's existing 413 operating reactors provide about a quarter of the world's low-carbon electricity. Across the globe there is strong interest in how nuclear energy can contribute to achieving the 2050 climate objectives. The 28th United Nations Climate Change Conference (COP28), in the 'first global stocktake of progress toward meeting the goals of the Paris Agreement', called on 'parties to contribute to the following global efforts, in a nationally determined manner, taking into account the Paris Agreement and their different national circumstances, pathways and approaches (...) accelerating zero- and low-emission technologies, including, inter alia (...) nuclear'. COP28 also saw 22 world leaders sign a pledge to triple nuclear energy capacity by 2050.

> The world's existing 413 operating reactors provide about a quarter of the world's low-carbon electricity.

At the same time, nuclear fuel cycle supplies remain sensitive to geopolitical developments – particularly as a result of Russia's war of aggression in Ukraine – that place upward pressure on the market. In April 2023, the Sapporo 5 nations (Canada, France, Japan, the United Kingdom, and the United States) issued a 'Statement on Civil Nuclear Fuel Cooperation' [60] in which they committed to a multilateral effort to establish a global commercial nuclear fuel market, collaborating on strategic opportunities in the nuclear fuel supply chain to:

- further reduce their countries' reliance on Russia in the nuclear fuel supply chain in the long term; and
- increase the availability of commercial free-market alternatives in the supply of civil nuclear technologies to other countries.

> Nuclear fuel cycle supplies remain sensitive to geopolitical developments – particularly as a result of Russia's war of aggression in Ukraine – that place upward pressure on the market.

In addition, a bill [61] passed by the US House of Representatives on 11 December 2023 will prohibit imports into the US of unirradiated low-enriched uranium produced in Russia.

Spot prices across the nuclear fuel cycle continued to rise in 2023. Compared to late 2022, average uranium prices rose by 26%, reaching USD 62.13 per pound of U_3O_8, while conversion costs amounted to USD 40perKgU in both the EU and North American markets, reaching record highs. Average enrichment costs rose to USD 137.42 per kgSWU, a 55% increase. [62]

Long-term prices also rose in 2023. Compared to late 2022, average uranium prices increased by 20% to reach USD 57.83 per pound of U_3O_8. The historically low long-term conversion price, having averaged more than USD 24 per KgU in 2022, reached USD 30 per KgU in 2023. Average enrichment costs rose to USD 144.75 per kgSWU, a 25% increase compared to average prices in 2022. [63]

Higher prices have prompted investors to consider bringing mothballed facilities back on stream and develop new ones.

Uranium conversion capacity in western countries had been mothballed after years of surplus supply. Additional conversion capacity is now being brought back on stream in the US and there is some limited scope for expanding capacity or production in existing facilities in Canada and France, and for restarting capacity at the UK's Springfields facility. However, because such efforts take time and require capital

60 Statement on Civil Nuclear Fuel Cooperation Between the United States, Canada, France, Japan, and the United Kingdom: https://www.energy.gov/articles/statement-civil-nuclear-fuel-cooperation-between-united-states-canada-france-japan-and.
61 Prohibiting Russian Uranium Imports Act: https://www.congress.gov/118/bills/hr1042/BILLS-118hr1042rh.pdf. On 30 April 2024, the bill also passed the US Senate by a unanimous vote; on 13 May, the US President signed the Prohibiting Russian Uranium Imports Act.
62 UxC month end prices.
63 UxC month end prices.

expenditure, the conversion market can be expected to remain tight in the short to medium term, with significant competition to secure fuel services under long-term contracts.

As a result of energy security concerns and in the face of possible trade restrictions, customers are also looking at long-term trusted supplies in the enrichment segment. As a result, enrichment capacity expansions have been initiated in Europe and the US.

2023 saw several announcements and developments regarding modular reactors in Europe and elsewhere. In the years ahead, it is anticipated that new fuel supply technologies will be required. Whereas light water reactors (LWRs) and small modular reactors (SMRs) can harness existing, well-established fuel sources, advanced modular reactors (AMRs), which explore various technological options and require new types of fuel based on low-enriched uranium plus (LEU+), high-assay low-enriched uranium (HALEU), thorium or plutonium (in different chemical and physical forms) will require the development of a new fuel supply chain.

4.1. Primary uranium supply

In 2023 the global uranium market continued to face challenges related to the geopolitical situation. Russia's war in Ukraine, the coup d'état in Niger, production issues, dwindling secondary sources and stronger demand impacted the uranium market and influenced supply and demand forecasts. Restrictions affecting trade with Russia, mounting concern over future supplies and production issues impact the market. These concerns are mirrored by upward pressure on uranium prices. In some scenarios, total demand for uranium is expected to grow at a significant pace in the coming decade. Various factors – decisions to extend the life of nuclear power plant and reverse retirements, and applications other than electricity generation – are liable to increase the pressure to open new mines and make new investments.

> Total demand for uranium is expected to grow at a significant pace in the coming decade.

In May, the French company Orano Mining signed a global framework partnership agreement with the Nigerien government on Orano's long-term uranium mining activities in the country. After the military coup in Niger in late July, uranium production at the Somaïr mine was provisionally interrupted for early maintenance due to disruption in the supply chain operations in the country are likely to be hampered by logistics concerns, which may also impact Global Atomic Corp's plans to operate the Dasa mine from 2025; after financing woes, the project's future remains uncertain. Notwithstanding, Orano reported progress with its Cominak project and Imouraren studies, in line with an agreement signed earlier with the Nigerien government.

Meanwhile, the McClean Lake joint venture between Orano Canada and Denison Mines Corp announced that it would restart uranium mining using the new 'surface access borehole resource extraction' (SABRE) mining method. Denison also announced the completion of feasibility studies of the Wheeler river's Phoenix (ISR) and Gryphon (conventional underground) deposits, described as potential competitors for lowest-cost uranium mining operations globally.

2023 saw the joint publication by IAEA and the OECD's Nuclear Energy Agency of the 'Red Book', the authoritative reference for uranium resources, production and demand, published every two years. According to the publication, Canada's high-grade uranium deposits remain the prime target for uranium exploration, not least as a result of recently discovered large deposits. The report also cites developments in other parts of the world, including Saudi Arabia (Ghurayyah and Jabal Sayid) for the first time.

Noteworthy events included the protocol signed by Orano to develop the Zuuvch Ovoo mine in Mongolia and the progress report by Katco on the South Trtkuduk uranium mining site in Kazakhstan, where processing is expected to start in 2024.

Table 6. Natural uranium production in 2022 (compared to 2021, in tonnes of uranium equivalent).

Region/country	Production 2022	Share in 2022 (%)	Production 2021	Share in 2021 (%)	Change 2021/2022 (%)
Kazakhstan	21 227	43.4%	21 819	45.6%	-2.7%
Canada	7 351	15.0%	4 693	9.8%	56.6%
Namibia	5 613	11.5%	5 753	12.0%	-2.4%
Australia	4 087	8.4%	4 192	8.8%	-2.5%
Uzbekistan	3 300	6.7%	3 520	7.4%	-6.3%
Russia	2 508	5.1%	2 635	5.5%	-4.8%
Niger	2 020	4.1%	2 248	4.7%	-10.1%
China	1 700	3.5%	1 600	3.3%	6.3%
Others	708	1.4%	695	1.5%	1.9%
South Africa	200	0.4%	192	0.4%	4.2%
Ukraine	100	0.2%	455	1.0%	-78.0%
United States	75	0.2%	8	0.0%	837.5%
Total	**48 889**	**100.0%**	**47 810**	**100.0%**	**2.3%**

Source: Data from the WNA and specialised publications (because of rounding, totals may not add up). 2023 data not available at the date of publication of the report.

Japan, which last year listed uranium as a critical mineral, announced funds for mining projects (including for rare earth elements) with the stated intention of reducing its raw materials dependence on Russia and China. According to METI, Japan's uranium reserves are estimated at 6 600 tonnes, potentially enough to meet internal demand for roughly 6 years. However, Japan has no domestic uranium production and relies entirely on imports from countries such as Australia, Canada and Kazakhstan.

Prompted by the continued strength of the uranium market and rising prices, US Energy Fuels announced preparatory work on 2 new mines in Wyoming and Colorado for uranium production within a year and progress towards approval for 3 other projects. On the other hand, Peninsula Energy announced significant delays to its Lance ISR project, due to termination of a resin processing agreement with Uranium Energy Corp. Peninsula has adopted a plan to accelerate the in-house development of an expanded production plant at Lance to produce high-quality yellowcake. The company expects to restart Lance in late 2024.

In Australia, Boss announced strong drilling results and reported that commissioning was on track to deliver the first drum of uranium from the Honeymoon project.

Amid plans for renewed nuclear investment, Sweden announced it was considering lowering obstacles to uranium mining. Meanwhile, Australia-based Aura Energy hopes to extract uranium as a by-product from its 100%-owned Häggån polymetallic project in Sweden. There is currently no uranium mining in Sweden.

4.2. Secondary sources

As with other energy minerals, imbalances between demand for uranium and primary production are traditionally bridged through inventory drawdowns, which can include commercial or government-held inventories. In the case of uranium, such secondary sources may – depending on economic factors – also include depleted uranium upgrades, or natural uranium saved by uranium enrichers by means of underfeeding.

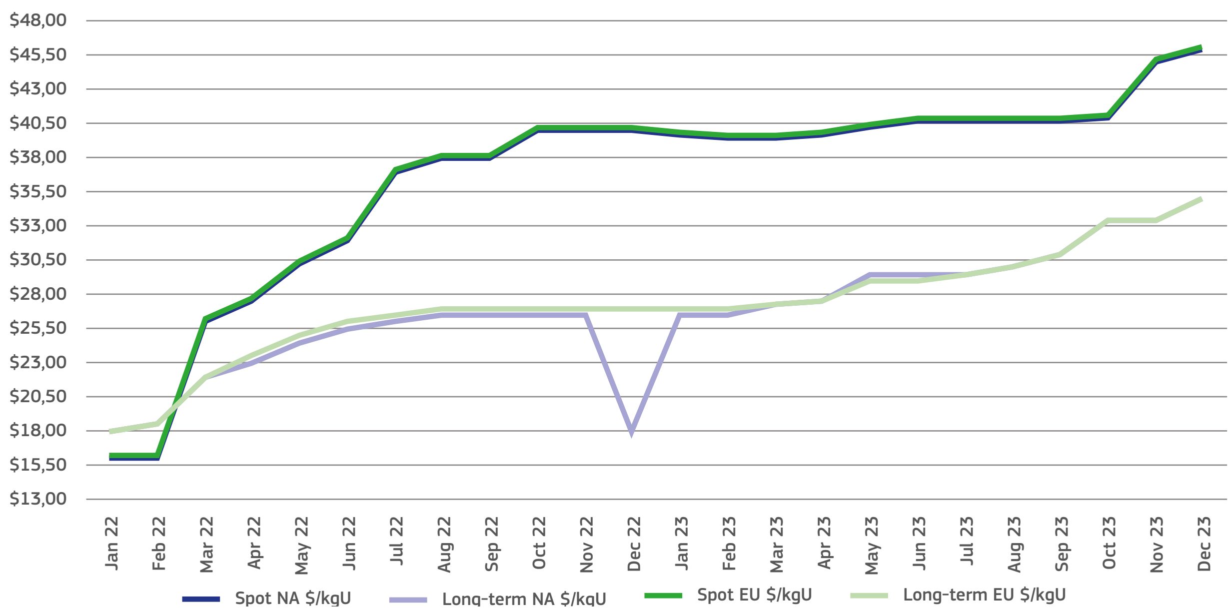
Forecasting such imbalances remains challenging, as reliable global data on secondary and other sources of uranium are not readily available. However, most analysts anticipate faster depletion of secondary sources towards the end of the current decade. This may be compounded by the rising trend in enrichment demand and separative work unit (SWU) prices, which are expected to reduce the scope for underfeeding, and by the build-up of physical uranium holdings in the hands of private trusts such as Sprott Physical Uranium Trust (SPUT), Yellow Cake plc, Zuri-invest, and ANU Energy.

However, such trends could over time be offset by increased use of recycled uranium and plutonium as MOX fuel if accompanied by development of appropriate fuel cycle capabilities. While depleted uranium may sometimes be perceived as waste for geological disposal, it is best described as a strategic resource readily useable in oxide form to manufacture MOX fuel. Furthermore, developments in laser enrichment could allow cost-effective re-enrichment of high-assay tails to form a secondary source of natural uranium and further alter assumptions regarding secondary sources heading into the next decade.

4.3. Conversion

The uranium conversion market is characterised by the small number of operating facilities worldwide. It has experienced significant variations in the past, but none as striking as the recent surge in prices. This trend reflects tightened market conditions at various stages in the cycle, resulting in increasing demand from western suppliers.

Figure 13. Uranium conversion price trends (in USD)



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

As a strategic step, conversion is one of the activities earmarked for investment in the West in the joint declaration signed on the margins of the Sapporo G7 summit. While it may be argued that a resumption of idled capacity (e.g. in the US and possibly the UK) and an expansion of existing capacity or production (e.g. in France and Canada) could help ease market pressures, any new investments are likely to be effective only in the longer term.

Conversion is one of the activities earmarked for investment in the West in the joint declaration signed on the margins of the Sapporo G7 summit.

The Metropolis Works plant, with a nominal capacity of 15 000 tU, operated until 2014 at only 7 000 tU on economic grounds and was placed in a 'ready idle' state in 2017 and restarted in 2023. While no decision has been taken, it has been reported that the former capacity could be reinstated, and option for a capacity increase to 10 000 tU by 2028 is being considered.

Other noteworthy developments in 2023 included a UK government match-funded £13m award to Westinghouse to bring uranium conversion capability back to the Springfields site, potentially adding up to 7 500 tU in capability for converting both reprocessed uranium and naturally enriched uranium by the end of the decade. Plans to commission such a facility (formerly dubbed Hex Line 3 or ECHO) are not new but had previously been shelved for economic and other reasons.

In France, Orano reported progress on its Philippe Coste conversion plant, where production was more than 10 000 tU in 2023 (compared to 8 900 tU for 2022). The ramp-up will continue until 2025.

Observing how events in Ukraine have been driving utilities to reposition themselves, Cameco also announced revised objectives for its Port Hope conversion facility amid historic price and demand levels, with 12 000 tU/year now the target. The plant also saw the arrival of the first batch of uranium mined at Ukraine's eastern mining and processing plant (SkhidGZK).

Several other noteworthy developments related to the deconversion of uranium hexafluoride into a more stable uranium oxide. Again, in the US, a first major shipment of deconverted depleted uranium from the Paducah site was reported. In the UK, Urenco announced plans to expand its Tails Management Facility at Capenhurst. Russia's Zelenogorsk site reportedly made further progress towards the commissioning of a second plant (W2-ECP) for the deconversion of depleted uranium hexafluoride.

Table 7. Commercial UF_6 conversion facilities

Company	Nameplate capacity in 2023 (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%

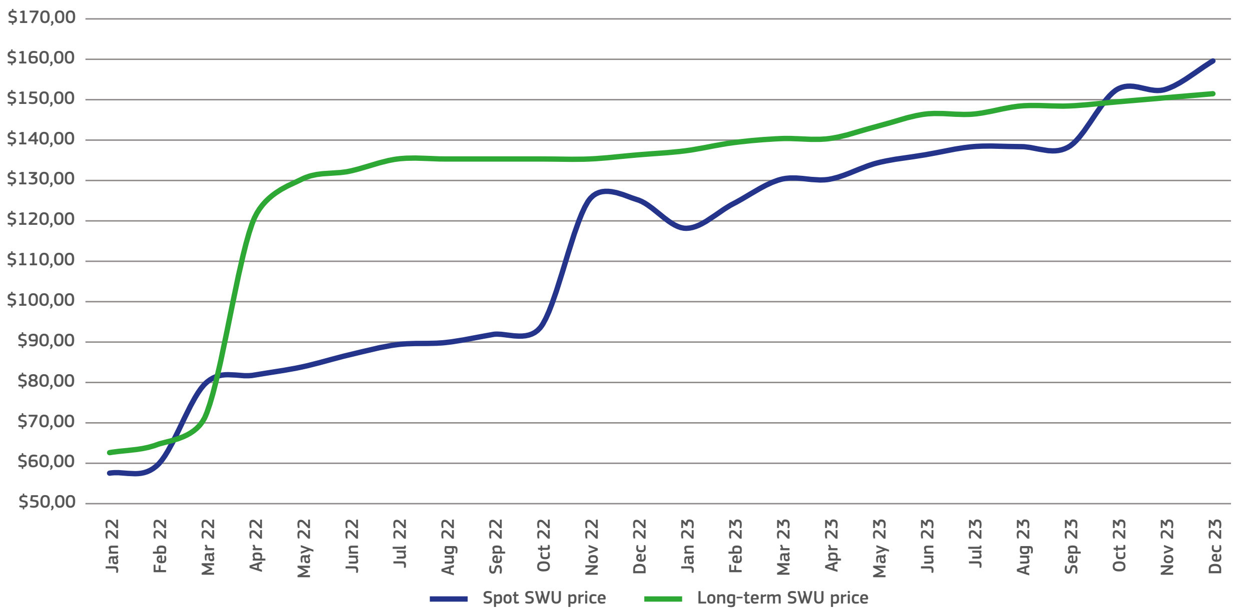
Because of rounding, totals may not add up.
Source: www.world-nuclear.org
** Approximate capacity installed 10 500 tU*
*** Information on China's conversion capacity is uncertain.*
**** Activity suspended since end of 2017.*

4.4. Enrichment

Different processes can be used to produce enriched uranium, with gas centrifuge technology currently the most common. Being proliferation-sensitive, enrichment technology is available only to a limited number of governments, who entrust it to an even smaller number of commercial operators. Amid the current geopolitical tensions and other shocks to global energy markets, it is therefore noteworthy that such a sensitive market segment seems to have embarked on significant change.

As reported by Urenco in its annual report, 2023 not only saw higher SWU market prices, but also the repositioning of users. In particular, the company noted that for the first time it was doing business with Bulgaria and Canada. Urenco announced plans to extend and refurbish enrichment capacity at the company's facilities. This includes new centrifuge cascades at the Eunice plant in the US, expanding capacity by 15%, the re-fitting of a hall in Germany with more modern centrifuge technology, and a licence to extend capacity and add 750 tonnes of SWU per year from 2027 at the facility in the Netherlands. At the same time, the UK government announced a series of projects, including the award of over £9.5 million from the nuclear fuel fund to Urenco UK to help develop enrichment capability for higher assays (LEU+ and HALEU) at the Capenhurst site.

Figure 14. 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.

Likewise, Orano in France unveiled ambitious plans to expand capacity by 30% at its Georges Besse 2 plant, priced at EUR 1.7bn and adding some 2.5 million SWU from 2028. The company also applied for a licence to produce uranium enriched at higher assays.

Enrichment of recycled uranium is another factor that could influence trends in this market segment. While Russia had long been the sole supplier of enrichment services for recycled uranium now also the Urenco's facility in the Netherlands provides this service. In addition, two modules of Orano's facility in France could also enrich reprocessed uranium.

While the traditional focus has been the production of enriched uranium for large power plants, there is now the prospect of smaller units. Certain SMRs and AMRs call for higher assays of low-enriched uranium fuel (LEU+, HALEU) so far not used in commercial nuclear fleets. Higher assays are particularly important for future users of smaller reactors unable to rely on uranium-plutonium mixed fuels.

HALEU also plays a part in key non-power applications such as medical isotope production, process heat, marine propulsion, and space systems. 2023 saw an array of such project announcements, from a high-temperature reactor for the Dow chemical company's site at Seadrift, Texas, to a project for cislunar applications. However, such applications are competing for limited HALEU stocks. As far as medical applications are concerned, the US administration determined that up to 1 500 kgU HALEU to support molybdenum-99 production (for medical isotopes) will not have any adverse material impact on the domestic nuclear fuel cycle industries.

Table 8. 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*

These developments are all driving change in the structure of the uranium enrichment industry and associated segments.

The year saw the first delivery of HALEU produced at the centrifuge plant in Piketon, Ohio, with Centrus expected to embark on a second phase for a full year of HALEU production at a rate of 900 kg/year. However, delivery has been impacted by shortages of 5B cylinders, focusing renewed attention on the logistics of HALEU production. Such issues have been duly acted on by Orano and Urenco, who concluded a consortium agreement for testing and developing the new 30B-X cylinder designed to transport uranium enriched by up to 20%.

Meanwhile, the US Department of Energy issued draft requests anticipating the production of between 5 and 145 metric tonnes of HALEU over a 10-year period. The initial sources for such deliveries are likely to involve downblending existing stockpiles of highly enriched uranium (HEU). The US National Nuclear Security Administration announced it was awarding BWX Technologies a potential USD 116.5 m (EUR 107 m) contract to produce more than two metric tonnes of feedstock for advanced reactors over the next 5 years. Nevertheless, such developments are likely to help drive further change in the enrichment services segment of industry towards HALEU production.

In Europe, concerns about the geopolitical situation have also prompted calls for strategic autonomy. In April, a Euratom-funded preparatory phase for a European production capability was launched to secure a supply of HALEU from 2030-2035 onwards. This development comes in response to the assessment in the 2022 ESA study on HALEU options, and hopefully will be heeded by industry.

> In Europe, concerns about the geopolitical situation have also prompted calls for strategic autonomy.

4.5. Fuel fabrication

Unlike conversion or enrichment services, which mostly involve fungible uranium, fuel fabrication is an engineering service that requires preparing fuel assemblies to the exact requirements of the customer reactor unit. While some degree of competition is theoretically possible, vendor consolidation over the years has led to a high degree of concentration.

In some subsegments, such as fuel with hexagonal geometry, fuel using mixed oxides and fuel using reprocessed or blended uranium, competition is even more restricted. Nonetheless, for reasons parallel to those mentioned above, this segment is also undergoing marked changes.

In September, Westinghouse announced the delivery of its inaugural reload batch of VVER-440 fuel assemblies to the Rivne-2 unit of Energoatom, Ukraine's state-owned nuclear utility. Energoatom had already implemented a nuclear fuel diversification project for VVER-1000 reactors, and it is now the sole power generation company operating VVER reactors with alternative fuel design.

Framatome announced plans for the construction of a nuclear fuel fabrication facility in the UK to manufacture nuclear fuel for large pressurised water reactors (PWRs) and light water SMRs.

Global Nuclear Fuel-Americas (GNF-A) applied for a licence amendment to hold and use special nuclear material to fabricate fuel using uranium enriched with up to 8 weight percent uranium-235 (LEU+) at its US facility in Wilmington, North Carolina.

Cameco completed the acquisition of Westinghouse, in partnership with Brookfield. Westinghouse Electric Company announced that the UK government's nuclear fuel fund had awarded three grants to upgrade and expand the Springfields fuel fabrication facility in support of the UK's next-generation nuclear reactors.

The Canadian Nuclear Safety Commission (CNSC) decided to renew the licence held by Cameco Fuel Manufacturing Inc. (CFM) for its facility located in the municipality of Port Hope, Ontario.

Fuel rod

2023 also saw Framatome announce steps to restart the manufacture of fuel using enriched reprocessed uranium (URE 15 ppb) by submitting an application for an extended licence to the national safety authority. According to earlier Framatome statements, corresponding production at its plant in Romans-sur-Isère could double in volume from 2025.

Also, at Romans-sur-Isère, Framatome's CERCA Research and Innovation Laboratory (CRIL) announced the completion of a key step towards monolithic molybdenum-uranium (U-Mo) fuel for the TUM FRM-II reactor, allowing the use of lower-enriched uranium thanks to higher density. Earlier in 2023, as part of the TRIGA International joint venture with General Atomics, the company also announced the completion of the first fabricated TRIGA metallic element in a decade at the site.

Such fuel fabrication capabilities at the Romans site are expected to contribute further to transatlantic projects for advanced micro-reactors such as the MARVEL reactor earmarked for construction at Idaho National Laboratory (INL). In December, operator Battelle Energy Alliance LLC (BEA) awarded TRIGA International a contract to fabricate TRIGA-like fuel for this liquid metal-cooled microreactor.

In 2023, the Advanced Nuclear Fuel (ANF) fuel assembly plant in Lingen applied to the Lower Saxony Ministry for the Environment, Energy and Climate Protection for a licence amendment, including changes to manufacturing and testing facilities to enable the production of hexagonal (VVER type) fuel assemblies. For this purpose, new machinery and systems in the area of fuel rod and fuel element production are to be installed in the production building while existing systems will be modified to comply with the fuel licensor's requirements.

Also worthy of note is a draft request issued by the US Department of Energy for converting HALEU from uranium hexafluoride to metal or oxide forms in preparation for fuel fabrication.

4.6. Reprocessing and recycling

Like enrichment, reprocessing technology is sensitive from a proliferation perspective, which means that commercial operations in this segment are necessarily restricted. The number of facilities capable of processing irradiated materials for the purpose of separating all or part of the contained elements is small and expected to remain so worldwide.

Growth in this segment has in the past been hampered by the limited prospects for nuclear power expansion.

In France, reprocessing capacity has been determined mainly by the requirement to process domestic fuel, but spare capacity has been sold via contracts to foreign fuel owners.

Other noteworthy developments in 2023 included the announcement by Japan's Federation of Electric Power Companies (FEPC) that it would work with France's Orano on demonstration R&D for the reprocessing of used mixed oxide (MOX) fuel. Japanese utilities are reportedly aiming to have at least 12 reactors utilising MOX fuel by 2030. Earlier in the year, Japan Nuclear Fuel Limited also announced that further delays were affecting completion of the Rokkasho reprocessing plant.

After announcing plans to build at least six new reactors by 2050, France launched a series of measures to ensure that back-end and fuel recycling facilities will remain in operation in France until the end of the century through investments in life-extensions and new-build.

In Belgium, a ground-breaking ceremony took place in Mol to mark the start of construction for a new-build facility to recycle radioactive residues from the production of medical radio isotopes. Set for commissioning in 2027, the RECUMO process is intended to recover uranium from irradiated medical radio isotope fission (Mo-99) production targets. The process builds on experience acquired previously by the national Studiecentrum, in which a chemical yield of roughly 96% was achieved.

4.7. Storage and repository of nuclear spent fuel

In Germany, the federal company for radioactive waste disposal (BGE) reported that while construction of the Konrad final repository for low- and intermediate-level radioactive waste is well advanced, project completion has been delayed. Final disposal is expected to begin in 2030.

In Finland, the deep geological repository is nearing completion. A platform designed for remote operation under difficult conditions was tested at a depth of 430 metres below ground, and Posiva drilled the first deposition holes for final disposal. A trial run for final disposal is set to start in 2024.

Andra's request to the French Nuclear Safety Authority (ASN) for permission to commence construction of Cigeo, a deep geological repository situated near Bure, was deemed admissible. This milestone permits the initiation of the technical evaluation of the application, after numerous decades of preliminary research and development efforts.

Belgium's agency for the management of radioactive waste (Ondraf/Niras) granted a licence to build a surface disposal facility at Dessel.

The Dutch central organisation for radioactive waste (Covra) announced the construction of a new multifunctional storage building (MOG) for low- and intermediate-level waste.

EDF Energy announced the successful completion of the defueling of the first of two reactors at the Hunterston B advanced gas-cooled reactor (AGR) nuclear power plant in the UK.

Swiss authorities agreed that submission of the 2021 waste disposal programme by the national cooperative for the storage of radioactive waste (Nagra) met the legal mandate of those responsible for waste disposal.

Finally, Sweden's SKB signed a collaboration agreement for expanding the existing final repository for short-lived radioactive waste (SFR) in Forsmark. This involves six new waste vaults that will extend 240 to 275 metres into the bedrock.

5. Key achievements

5.1. 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. [(64)] The Agency was set up to take responsibility for the common supply policy for ores, source materials and special fissile materials, with the purpose of ensuring the regular supply of the materials concerned to Community users. The policy is based on the principle of equal access for all Community users to sources of supply.

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

The prerogatives of ESA stem from the Euratom Treaty and its secondary legislation. The Agency has the exclusive right to conclude contracts for the supply of nuclear materials coming from inside or outside the Community, as well as a right of option on nuclear materials produced in the Community. It also monitors transactions for the provision of services in the nuclear fuel cycle, including by acknowledging the notifications that market players must submit to it, giving details of their commitments.

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

In the interest of its Treaty missions, the Agency's Statutes [(65)] entrust it with a market observatory role to identify market trends that could affect the security of the EU's supply of nuclear materials and services. This mission extends to aspects of the supply of medical radioisotopes in the EU in the light of Council Conclusions on this issue. [(66)]

ESA also provides the Community with expertise, information and advice on any subject connected with the operation of the market in nuclear materials and services.

Governance

The Euratom Treaty has endowed ESA with legal personality and financial autonomy, enabling it to make independent decisions on matters within its remit. The Agency operates under the supervision of the European Commission. The Agency's Statutes set out its governance in more detail.

The Euratom Treaty has endowed ESA with legal personality and financial autonomy, enabling it to make independent decisions on matters within its remit.

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

The Supply Agency had an acting Director-General between October 2023 and April 2024. A new Director-General was appointed by the Commission and started in his functions on May 2024.

64 Treaty establishing the European Atomic Energy Community (consolidated version published in the Official Journal of the European Union, 2016/C 203/1).
65 Laid down by Council Decision of 12 February 2008 establishing Statutes for the Euratom Supply Agency (2008/114/EC, Euratom).
66 '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.

Advisory Committee

At its in-person meeting in April 2023, the Advisory Committee delivered its opinion on ESA's 2022 draft annual report and examined the short- to long-term security of the supply situation as presented by the Agency and the Commission. ESA provided an update on the security of supply of medical radioisotopes in the EU, presented its line on contracts with unreliable suppliers and announced that it had started preparing a first draft of its own specific provisions on access to Agency documents.

At its June online meeting, the newly nominated Committee for 2023-2026 elected its chairperson and the two vice-chairpersons.

At its December in-person meeting, the Committee discussed the short-and long-term security of supply of nuclear materials and the possibility of re-establishing a Working Group on Prices and Security of Supply. This was approved for the period of the next term of the Committee. The working group mandate has been agreed and members were proposed by written procedure.

Furthermore, the Committee gave a positive opinion on ESA's 2024 work programme and draft 2025 budget.

The Committee also examined the results of the survey on the effectiveness and efficiency of the arrangements for Advisory Committee meetings, as presented by ESA.

5.2. Principal activities

5.2.1. Contract management

In 2023, 228 files were registered. 75% of them concerned requests under Chapter 6 of the Euratom Treaty and its secondary legislation on the supply, processing, conversion, shaping, transfer, import or export of ores, source materials or special fissile materials, including of small quantities.

> In 2023, 228 files were registered.

A small proportion (around 7%) of the requests under Chapter 6 was about transfers, imports or export operations under Article 74 of the Euratom Treaty and the notification of related contracts that meet the criteria of the Commission Regulation on the transfer of 'small quantities' of nuclear materials. [67]

The remaining 93% are evenly split between notifications under Article 75 of commitments for the processing, conversion and shaping of nuclear materials, and requests to see approved the conclusion or renewal of agreements and contracts under Article 52. In the latter case, the requests are handled in accordance with the rules of 'simplified' procedure, after acknowledgement of the receipt of a complete file with all required originals, including the submission and/or the notification form as appropriate.

ESA Advisory Committee meeting December 2023

©Euratom Supply Agency

67 Commission Regulation (Euratom) No 66/2006 of 16 January 2006 exempting the transfer of small quantities of ores, source materials and special fissile materials from the rules of the chapter on supplies, OJ L 11, 17.1.2006, pp. 6-8.

Table 9. Contracts by type in 2023

Type of contract (*)	2023
Natural uranium (**)	**39**
Purchase/sale by EU utilities/end users	***23***
Multiannual	11
Spot	12
Purchase/sale between EU producers/ intermediaries	***0***
Multiannual	0
Spot	0
Exchanges and loans	***0***
Amendments	***16***
Special fissile materials	**50**
New contracts	***27***
Purchase by an EU utility/end user	18
Sale by an EU utility/end user	4
Purchase/sale between two EU utilities/ end users	0
Purchase/sale other	4
Exchanges / Loans	1
Contract amendments	***23***
Enrichment notifications (***)	**36**
New notifications	***26***
Notifications of amendments	***10***

(*) Transactions for small quantities (as under Art. 74 of the Euratom treaty), services (as under Art. 75 of the Euratom treaty) other than enrichment and information communicated on any contracts other than supply contracts are not included
(**) Including feed contained in EUP purchases
(***) Contracts with primary enrichers only

5.2.2. Security and diversification of the nuclear fuel supply chain

Diversification of supply sources, while contributing to the viability of the EU nuclear industry, remains an important means of ensuring security of supplies in the medium and long term.

Responding, in collaboration with the Commission departments to market and geopolitical uncertainties, ESA continued to follow the short-term challenges related to security of supply of nuclear materials and fuel, both from the economic perspective and in terms of inventory robustness. Thanks to the annual survey of market players, this analytical work also extends to medium- and long-term supply risks, integrating probable supply scenarios and the forecast reports sporadically released.

Based on its analyses, ESA has constantly adapted its procedures and approaches to strengthen the security of energy supply in the nuclear sector under the current circumstances.

The Agency has continued to advise users to enter long-term commitments where possible, particularly with regard to securely sourced conversion and enrichment services, and to limit exposure to providers headquartered in or controlled by high-risk jurisdictions, or heavily dependent on unreliable supply chains. ESA continued to encourage the diversification of suppliers and the creation of strategic inventories of nuclear supplies, while closely monitoring and discouraging sources of supply deemed to be of high risk.

At the same time, ESA continued to provide input to the Commission in view of possible additional policy and regulatory action or other measures that could be undertaken by the latter.

In collaboration with the Commission's nuclear safeguards department, ESA has been regularly monitoring the operational autonomy of nuclear power plants, taking into account the fuel currently available, as well as the forthcoming deliveries.

> ESA continued to encourage the diversification of suppliers and the creation of strategic inventories of nuclear supplies, while closely monitoring and discouraging sources of supply deemed to be of high risk.

ESA and the Commission energy department held regular meetings with the utilities most exposed to high-risk sources of supply. In this respect, the supply chains of nuclear fuels of hexagonal design (as used in Russian VVER reactors) as well as the situation about conversion and enrichment capacity continued to draw particular attention.

In accordance with its strategic objectives, ESA continued to closely monitor market developments and analyse them from an economic and industry viewpoint. The identification of market trends likely to affect the EU's medium- and long-term security of the supply of nuclear materials and services remains a top priority.

High Level Workshop on security of supply of medical radioisotopes

© Euratom Supply Agency

In this respect, ESA produced comprehensive statistical reports on nuclear market trends. These were based on data from contracts that the Agency concluded or acknowledged, information obtained from EU utilities through the annual survey at the end of 2022, and on market data from various sources. These findings are supplemented by insights into market developments gathered from specialised media, stakeholders and open sources.

ESA pursued its primary objectives for long-term security of supply. This includes ensuring that EU utilities have diverse sources of supply, avoiding excessive reliance on any single non-EU design or supplier, and sustaining the viability of the EU industry throughout the fuel cycle.

For years, ESA has recommended that utilities secure a substantial portion of their current and future requirements through multiannual contracts with diverse suppliers.

In line with this recommendation, 98% of natural uranium deliveries to the EU in 2022 were made under multiannual contracts, with the remaining 2% being spot contracts.

On mining origin, four major producing countries – Kazakhstan, Niger, Russia and Canada – contributed more than 90% to natural uranium deliveries to the EU, each with varying shares.

> ESA has recommended that utilities secure a substantial portion of their current and future requirements through multiannual contracts with diverse suppliers.

Previously identified challenges relating to the transport of nuclear fuel through regions in conflict, or those with increased logistical risks, continue to be present. However, the related difficulties are alleviated as alternative routes have been identified. The continuation of the Russian war of aggression against Ukraine nevertheless remains a source of uncertainty also in that respect.

Within its remit, ESA helped the Commission handle European Parliament questions, petitions and national parliament resolutions, as well as assess international agreements communicated under Article 103 of the Euratom Treaty. Likewise, the Agency provided input on matters within its remit related to the legislative work of the Commission.

Moreover, ESA received for the first time several requests for information about ESA requirements related to future plans for nuclear power generation. These were submitted by organisations based in Community countries less interested until now in the future of nuclear energy production.

Finally, the Agency received and successfully dealt with several questions from the public about itself in 2023.

5.2.3. Market monitoring and analysis

Market monitoring

Following the Russian war of aggression against Ukraine, ESA continued to monitor the impact of geopolitical developments in the EU and update its analysis of the current and future conversion and enrichment capacity worldwide. In its market analysis, ESA confirmed its previous conclusion that EU utilities' demand for both natural uranium and fuel fabrication and related services faces an increased risk related to Russian supply and the new geopolitical situation. Analysis from the nuclear industry (converters and enrichers) indicated that total open market conversion capacity may not be sufficient. Similarly, the capacity of the same open market sources to supply enrichment would be insufficient if the services from current non-open market players such as Russia were not available. The Agency assessed that replacing the additional conversion and enrichment capacity could take several years. European industry requires adequate signals to maintain and build-up capacity both for natural and reprocessed uranium, especially for conversion, fuel design and fabrication. This is because industrial investments would not be viable without some form of political and contractual commitment for the long term.

ESA continued to monitor the impact of geopolitical developments in the EU and update its analysis of the current and future conversion and enrichment capacity worldwide.

Annual Report 2022

In its 2022 annual report, ESA gave an overview of its own activities and developments in the nuclear fuel markets and nuclear energy, both in the EU and worldwide.

As in previous years, ESA conducted a survey of EU nuclear power operators in 2023. The survey provided a detailed analysis of supply and demand for natural uranium and for conversion and enrichment services in the EU in 2022. The Agency published three indices for 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.

The report set out ESA's findings and recommendations on supply and demand for nuclear fuels. It reflected the Agency's diversification policy and work on security of supply and discussed the security of supply of medical radioisotopes. As the political and economic events in 2021-2022 seriously impacted the global nuclear market, ESA's recommendations became more relevant and urgent than ever.

ESA's recommendations in its 2022 annual report took due account of the developments since the Russian war of aggression against Ukraine. ESA made eight groups of recommendations to boost the security of supply and overcome the current areas of vulnerability. For the first time, the ESA report included a specific group of recommendations on tackling vulnerabilities in the security of supply of medical radioisotopes.

ESA Annual Report 2022

© Euratom Supply Agency

The report was published on ESA's website in October and its print version was made available in January 2024. [68] The report was sent to the European Parliament, the Council and the Commission, and was presented to the Council Working Party on Atomic Questions.

Publication and knowledge sharing

ESA regularly publishes reports [69] and information on price trends on its website [70] to provide transparency in the EU's natural uranium market, reduce uncertainty and help improve security of supply.

In 2023, ESA's nuclear fuel market observatory issued four quarterly uranium market reports (the last one covering two quarters). The reports include general data about natural uranium supply contracts concluded by ESA or notified to it, and the quarterly spot price index for natural uranium. [71] The 2023 quarterly reports featured overview articles on Commission support to SMRs, ESA quarterly spot prices and VVER nuclear fuel developments. The Agency also issues a weekly nuclear newsletter for Commission staff.

68 ESA Annual reports: https://euratom-supply.ec.europa.eu/index_en.
69 ESA Publications: https://euratom-supply.ec.europa.eu/publications_en.
70 Market Observatory: https://euratom-supply.ec.europa.eu/activities/market-observatory_en.
71 Provided at least three spot contracts have been concluded.

5.2.4. Supply of medical radioisotopes

With the EU being dependent on Russian production of critical stable isotopes and some radioisotopes, security of supply challenges were experienced in the supply chain of medical radioisotopes essential for nuclear medicine.

The supply of precursor material to produce medical radioisotopes remains a particular concern. The EU is dependent on Russia for the enrichment of stable isotopes needed to produce several important medical radioisotopes, in particular Ytterbium-176 (Yb-176) needed to produce Lutetium-177 (Lu-177). [72] Enriched isotopes would be also needed in the longer term to develop non-fission alternative production routes for Technetium-99m (Tc-99m), Molybdenum-98 (Mo-98) and Molybdenum-100 (Mo-100), which are sourced partly from Russia at present.

In this respect, ESA continued to provide expertise and analysis of the situation to the appropriate services and forums and to the relevant Commission departments. The Agency regularly updated the Council Atomic Question Working Party [73] on the supply situation. ESA actively participated in the Commission's high-level workshop on stable isotopes in April 2023. It also liaised with the industry association Nuclear Medicine Europe (NMEU) to gather relevant information.

In addition, some EU research reactors that produce vital medical radioisotopes are dependent on Russian fuel and materials. In this respect, ESA continued to assess their dependencies on Russian supplies and continued to call for a revised risk assessment to avert security of supply vulnerabilities. Some EU research reactor operators that had already licensed alternative fuel phased out the Russian supply of fuel. Some participate actively in Euratom research projects to develop alternative fuel design and break the Russian monopoly on the supply of fuel to medium-power research reactors of original Soviet design.

SAMIRA

ESA contributes to the implementation of the Strategic Agenda for Medical Ionising Radiation Applications (SAMIRA). [74] SAMIRA is the energy sector's contribution to the EU's Beating Cancer Plan, and a response to the Council's conclusions on non-power nuclear and radiological technologies and applications.

The Agency leads activities aimed at securing the supply of source materials for radioisotope production. This means: (i) protecting the supply of high-enriched uranium until the full radioisotope production chain is converted to operate with high-assay low-enriched uranium (HALEU); and (ii) exploring options for the future supply of HALEU to 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 contributes to the further development of the European Radioisotopes Valley Initiative (ERVI), which is crucial for ensuring endorsement by a wide group of stakeholders and sufficient resources. The Agency closely cooperated in this area with the Commission.

European Observatory on the Supply of Medical Radioisotopes

In 2023, ESA continued its 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 the European Observatory on the Supply of Medical Radioisotopes with NMEU.

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. It is composed of representatives of the Commission, EU Member States, international organisations and industry.

Since its establishment, the Observatory has confirmed its importance. It has become a vehicle for gathering information (through industry participation) on potential shortages and then dispatching information to interested parties, sometimes directly through ESA. It enables industry to reach out promptly to appropriate EU bodies and services on awareness raising and response facilitation at Member State and Commission level.

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.

72 The EU is a large supplier of Lu-177, which has seen spectacular growth in recent years.
73 Council of the European Union – Working Party on Atomic Questions.
74 Commission Staff Working Document on a Strategic Agenda for Medical Ionising Radiation Applications (SAMIRA), SWD(2021) 14 final, 5.2.2021.

In 2023, the Observatory continued its close cooperation with the NMEU's Security of Supply Workgroup on the uninterrupted supply of Mo- 99/Tc-99m and Iodine-131 (I-131). Following a Mo-99/I-131 production disruption and outage of several reactors, 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 and the Health Security Committee.

The 19th plenary meeting of the Observatory, which was held in Prague in March 2023, saw the participation of around 40 members (from industry, international organisations and Member State administrations). The meeting was largely devoted to presentations and discussions on the current EU programmes that support research on safe use and a reliable supply of medical radionuclides, i.e. the TOURR, SECURE and PRISMAP projects. The Commission's Directorate-General for Research and Innovation presented the Euratom research programmes that support projects developing HALEU fuels for the production of medical radioisotopes, including new research calls announced under the Euratom Research and Training Work Programme 2023-2025. The Commission's Joint Research Centre (JRC) presented its activities on the supply of medical radioisotopes, namely the recent and planned expert & stakeholder workshops, the EC Knowledge Centre on Cancer launched in 2021 and targeted alpha therapy drug developments at JRC Karlsruhe, Germany. The European Medicines Agency (EMA) presented the subject of crisis preparedness and management of shortages for medicinal products and medical devices, namely Regulation (EU) 2022/123 in force since March 2022. It provides a framework for activities established by EMA to monitor and mitigate potential and actual shortages of medicinal products, including medical radioisotopes. In addition to those points, ESA, NMEU, the European Association of Nuclear Medicine (EANM) and the International Atomic Energy Agency (IAEA) gave updates on their activities. The Commission's Directorate-General for Energy presented SAMIRA and ERVI, with an invitation to the High-Level Workshop on Security of Supply of Medical Radioisotopes on 27 April 2023. The plenary meeting was followed by a technical visit to the Research Centre Rez and PET Centre.

The 20th plenary meeting of the Observatory was held in the JRC's premises in Karlsruhe in November 2023. NMEU, EANM, EMA, JRC and the Directorate-General for Energy gave updates on their activities. NMEU presented the global research reactor scheduling for the remainder of 2023 and for 2024. The European Nuclear Education Network representative discussed the final report of the 2020-2023 TOURR project (Towards Optimized Use of Research Reactors in Europe) aimed at evaluating the current and future needs for research reactors and neutron sources in Europe. The Nuclear Energy Agency presented its report 'The Security of Supply of Medical Radioisotopes: 2023 Medical Isotope Demand and Capacity Projection for the 2023-2027 Period' and gave an update on its planned future activities. The Technical University of Munich representative presented the HERACLES Consortium [75] activities related to the conversion of the European research reactors and gave an update on the status and future of the FRM-II Mo-99 production facility. ESA presented a new updated Mo-99/Tc-99m supply chart. The plenary meeting was followed by a technical visit to the JRC laboratories that handle nuclear materials (namely the Ac-225 development lab).

ESA presented the Observatory's activities and the results of its 2022 and 2023 meetings to the Council Working Party on Atomic Questions. It outlined the 2023 supply disruptions for medical radioisotopes and the related mitigation measures taken by the Observatory in response to them.

Participants of the XX Plenary of MR Observatory at EC DG JRC in Karlsruhe DE

© European Union 2023

Security of supply of nuclear materials for non-power uses

ESA continued to scrutinise the security of supply of HEU and High-Assay Low-Enriched Uranium (HALEU), which are required to produce medical radioisotopes and to fuel research reactors.

ESA continued to assist users who still need supply of HEU until they convert their research reactors to HALEU, in line with international nuclear security and non-proliferation commitments. In 2023, in cooperation with the US and the Euratom Member States concerned, ESA reviewed progress in implementing the Memorandum of Understanding with the US Department of Energy-National Nuclear Security Administration [76] (DoE-NNSA) on the exchange of HEU.

75 The HERACLES Consortium: https://heracles-consortium.eu/.
76 "Memorandum of Understanding between the Department of Energy/National Nuclear Security Administration (DOE/NNSA) of the United States of America and the Euratom Supply Agency concerning the Exchange of Highly Enriched Uranium Needed for Supply of European Research Reactors and Isotope Production Facilities", originally signed in 2014 and renewed for the next 5 years in 2021.

In 2023, in cooperation with the US and the Euratom Member States concerned, ESA reviewed progress in implementing the Memorandum of Understanding with the US Department of Energy on the exchange of HEU.

5.2.5. Cooperation with stakeholders and partners

Throughout 2023, ESA continued contacts with EU authorities, utilities, industry and nuclear organisations to strengthen the security of supply of nuclear materials in light of the Russian war of aggression against Ukraine. It monitored market developments in view of the new market situation and provided advice and follow-up to ensure appropriate application of the common supply policy and mitigation of new risks.

ESA worked closely with the Commission to promote diversification of supply and contributed to the work of the Commission departments in that area. In the context of the REPowerEU initiative, ESA engaged together with the Commission in a multilateral assessment of demand for, and capacity of, front-end nuclear fuel cycle services in like-minded non-EU countries.

The Agency held regular meetings with utilities to discuss risk preparedness and implementation of mitigation measures. It also met with the EU nuclear industry to share information and market outlook.

The Agency has long-standing and well-established relationships on nuclear energy with international organisations, namely IAEA, the Nuclear Energy Agency and nuclear industry associations. In 2023, ESA continued to cooperate with these organisations by participating in working groups, conferences and seminars. It continued to support the IAEA expert group created in July 2021, which produced a technical document on global secondary uranium supplies in November 2023. [77] ESA supported the joint Nuclear Energy Agency/IAEA Uranium Group, which is responsible for publishing the 2-yearly report 'Uranium resources, production and demand' ('the Red Book'), [78] 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.

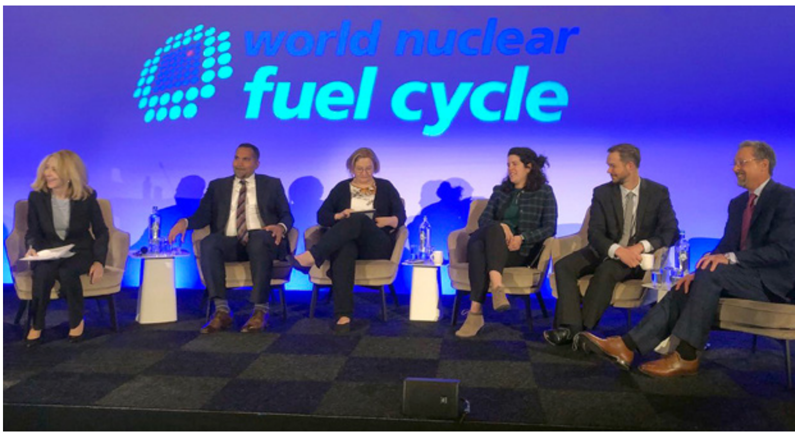
In February 2023, the Agency presented 'Securing the European fuel supply – Risks and Mitigation Measures in the Short and Long Term' at the Energiforsk Annual Nuclear Conference. Nordic companies in the nuclear business, especially from Sweden and Finland, networked and discussed how to build and strengthen the network of international and local suppliers in order to ensure a fast and secure development of new nuclear power.

The Agency's market analysis, nuclear fuel cycle outlook and security of supply policy were presented at the World Nuclear Fuel Cycle forum and the Symposium on Uranium Raw Material for the Nuclear Fuel Cycle (URAM-2023).

At the June conference of Nucleareurope, ESA provided insights into the supply situation and outlook as panellist in the session 'Guaranteeing energy sovereignty'. The Agency presented the information from its 2022 annual report on the current EU supply and how it projects future requirements vs capacity in terms of uranium supplies and conversion & enrichment capacities.

ESA's annual report analysis, conclusions and recommendations were also the subject of the European Nuclear Society event 'Fuelling Europe's Future – Uranium Supply, Conversion and Enrichment' in October. The focus was once again on the challenges of nuclear fuel cycle supplies in the face of the current geopolitical situation.

World Nuclear Fuel Cycle Conference



77 IAEA (International Atomic Energy Agency) Global Inventories of Secondary Uranium Supplies, Vienna, 2023): https://www.iaea.org/publications/15446/global-inventories-of-secondary-uranium-supplies.

78 NEA (Nuclear Energy Agency), Uranium 2020: Resources, Production and Demand, OECD Publishing, Paris: https://www.oecd-nea.org/jcms/pl_52718/uranium-2020-resources-production-and-demand.

In September, ESA attended the 2023 World Nuclear Symposium in London. It met nuclear industry, utilities and emerging EU market participants, providing insights into the market situation, learning about market developments and exchanging information on existing and future supply challenges.

In December 2023, ESA attended the conference 'The EU as a Regional International Organisation' organised by the Asser Institute and the Amsterdam Centre for European Studies in The Hague, Netherlands.

ESA moderated the European Nuclear Society's special event 'Beating Cancer – Turning the tide with medical isotopes', organised as part of the European Research Reactor Conference held in April in Antwerp, Belgium. The event gave the audience the opportunity to learn more about the remarkable developments in the field of nuclear medicine and discuss the challenges ahead.

In September, ESA was invited to give a speech about the work of the European Observatory at the EU Policy Symposium on Supply and Shortages of Radiopharmaceuticals at the Annual Congress of the European Association of Nuclear Medicine held in Vienna, Austria.

In November, ESA chaired a session on 'Landscape and challenges for medical radionuclide supply and research in the EU' at the workshop on 'Research and Innovation for Sustainable Medical Radionuclide Supply in the EU' organised by the JRC in Karlsruhe. The event gathered key stakeholders from academia, industry, research and health policymakers to discuss synergies that can keep the EU at the forefront of research and innovation, ensuring secure radionuclide supply and expediting the process from R&D of radiopharmaceuticals to clinical trials.

ESA in EANM Annual Conference 2023

© Euratom Supply Agency

6. Management

Legal status

ESA has been granted legal personal and financial autonomy [79] under the Euratom Treaty [80] with legal personality and financial autonomy. Operating on a non-profit basis, ESA is supervised by the European Commission. Detailed governance and management aspects are outlined in the Agency's Statutes. Since 2004, ESA has been headquartered in Luxembourg, with a seat agreement drawn up between the Grand Duchy of Luxembourg and the European Commission.

6.1. Budgetary and financial management

The European Commission is responsible for adopting ESA's budget and ESA's Director-General serves as the authorising officer for executing that budget. For its financial operations, ESA complies with the relevant provisions in its Statutes and the EU Financial Regulation, [81] along with accounting rules and methods set by the European Commission. ESA covers part of its operational costs through its own budget, while the European Commission directly funds another portion.

Budget

ESA's budget for the financial year 2023, amounting to EUR 228 000 [82] (which comes solely from the EU budget contribution under Section III – Commission, budget item 20 03 14 01 'Euratom contribution for operation of the Supply Agency'), was adopted by the European Commission on 14 December 2022.

Since the departure of its accounting officer in January 2023, and given the inability to find a suitable replacement, ESA's accounting officer role is now shared with the Translation Centre for the Bodies of the European Union. This collaborative arrangement was formalised through a service level agreement in March 2023.

To cover the provision of accounting services to ESA, an amendment [83] to ESA's budget for the financial year 2023 was adopted later in the year, increasing its budget by EUR 30 160 to EUR 258 160.

The adopted budget after amendment was almost 55% more than that of 2022. The increase is mainly due to the continued development of the Nuclear Observatory and ESA Management of Information (NOEMI) IT system and the provision of accounting services to the Agency.

ESA's revenue and expenditure were in balance.

Budget execution

During the year, the Director-General signed two decisions involving internal budget transfers deemed essential -specifically, reallocating funds from one budgetary article to another to address emerging requirements.

On 31 December 2023, ESA's budget execution of 2023 funds was evaluated as high, standing at a total of EUR 254 212.46 (98.47%) in executed commitments.

The payments executed on 2023 commitments amounted to EUR 122 916.67, giving an implementation rate of 47.61% of available appropriations.

The payments executed on commitments made in 2022 amounted to EUR 101 304.31, i.e. 97.74% of the outstanding payment allocations.

The operating costs that ESA covered with its budget included:

- development of the NOEMI nuclear contracts management application and maintenance of a stand-alone computer centre;
- Advisory Committee meetings;
- duty travel;

79 Article 54 of the Euratom Treaty.
80 Treaty establishing the European Atomic Energy Community (OJ L 27 6/12/1958 p534).
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 Commission Decision C(2022) 9491 of 14.12.2022.
83 Commission Decision C(2023) 5332 of 9.8.2023.

- participation in conferences;
- subscriptions to nuclear market media and data sources;
- ESA publications and communication activities.

In-kind contribution from the Commission

A significant proportion of ESA's administrative expenses is covered directly by the European Commission budget, including salaries, premises, infrastructure, training, and some IT services and equipment. In an internal estimate for 2023, the salaries of ESA staff were calculated at EUR 2 087 800 (EUR 1 937 817 in 2022). Other operating costs covered by the Commission included:

- EUR 558 090 – for buildings and digital workplace-related expenses (EUR 467 708 in 2022);
- EUR 92 954 – for hosting the NOEMI IT system (EUR 84 644 in 2022).

These off-budget expenditures and the underlying transactions are not acknowledged in ESA's accounts but are included in the Commission section of the EU annual accounts.

Financial accounts

In 2023, the assets owned by ESA totalled EUR 1 058 925.85 (EUR 932 901.66 in 2022). They were financed by liabilities of EUR 131 218.89 (12.39%) and equity of EUR 927 706.96 (87.61%).

The 2023 provisional accounts, budget outturn and report on budget implementation were submitted to the European Court of Auditors and the Commission's Accounting Officer on 28 February 2024. The final accounts were issued on 7 June 2024. After receiving a positive opinion from the Advisory Committee, they were submitted to the EU institutions on 28 June 2024.

ESA Offices in Luxembourg

6.2. Human resources

<table>
<tr><th>Human resources</th><th colspan="3">2023</th></tr>
<tr><td>Number of officials (or temporary agents)</td><td>Authorised [84]</td><td>Actually filled as of 31.12.2023</td><td>Effective throughout the year</td></tr>
<tr><td>Administrators (AD)</td><td>7</td><td>7</td><td>7.8</td></tr>
<tr><td>Assistants (AST)</td><td rowspan="2">10</td><td>7</td><td>6.3</td></tr>
<tr><td>Assistants/secretarial (AST/SC)</td><td>2</td><td>2</td></tr>
<tr><td>Total</td><td>17</td><td>16</td><td>16.1</td></tr>
</table>

Staff allocation

ESA staff are Commission civil servants (officials) and the number of staff set out in ESA's establishment plan is incorporated into the Commission's overall staff numbers. By the end of 2023, ESA had filled 16 posts: seven administrators (AD); seven assistants (AST); and two assistant/secretarial posts (AST/SC). There were three new recruitments in 2023: one to replace a departing staff member; and two to replace retired staff. One administrator (AD) post – Head of Agency – has been unoccupied since 1 October. ESA received no new posts in 2023.

As in previous years, the recruitment of Contract Agents and Assistants in Luxembourg remained difficult in 2023, due to the discrepancy between salary levels and the high cost of living. Due to the small size of the Agency, it is critical to be able to fill all vacated posts at the shortest possible notice.

Equal opportunities

ESA staff is gender balanced at all levels and the Agency offers equal career opportunities for all. In 2023, the staff was composed of eight women (50%) and eight men (50%). Equal opportunities irrespective of gender applied to all teams, as well as to the Agency's two managerial positions.

Furthermore, at the end of 2023, 12 different EU nationalities were counted among ESA's 16 staff members.

6.3. Information management and communication

NOEMI

NOEMI is the IT system supporting ESA's core operations. It hosts data from contracts related to the supply of nuclear materials and services in the nuclear fuel cycle, as well as regular data provided by ESA's partners (e.g. annual reporting on supply by nuclear utilities companies). It also supports the handling of these data, helps to monitor the nuclear market, and reports on results and trends. The NOEMI system became operational in December 2021.

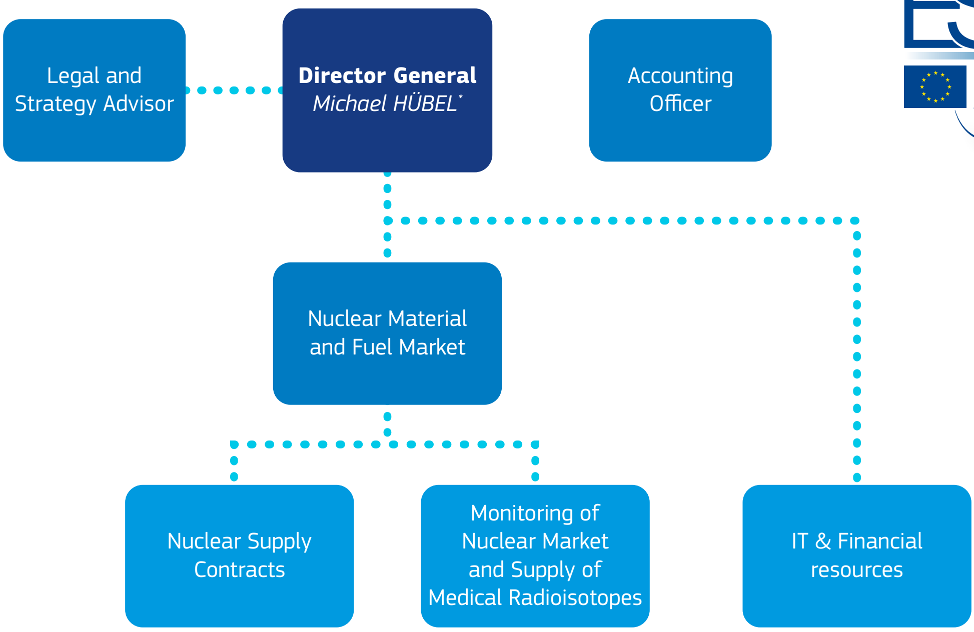
At the end of 2023, the Commission's Information Technology Cybersecurity Board gave a positive opinion to move forward with Phase 2 of the project.

NOEMI's Phase 2 aims to improve ESA's operational efficiency and effectiveness by expanding the system to cover contracts related to the supply of nuclear materials. Collecting and analysing data from these contracts, as well as notifications on related services, will enable NOEMI to provide ESA with meaningful assessments and conclusions.

The contract information handling process will also be streamlined under Phase 2, as it will seek to: (i) eliminate off-system follow-up, logging and monitoring; (ii) replace manual checks with automated ones; and (iii) provide model reports for common and standard use cases, that can be uploaded onto the corporate document management platform.

NOEMI Phase 2 aims to implement advanced business features, including nuclear supply contracts and services

84 Establishment plan under the EU General Budget 2023 OJ L58, 23.2.2023 p.1156, footnote (5).



(*) Since 1 May 2024

notification follow-up, visualizing and monitoring internal processes, managing and processing events, and monitoring statuses and notifications. It also seeks to enhance document and submission forms integration, bolster security measures, and restrict access based on business and hierarchical roles. Additionally, a key objective is to incorporate reusable solutions and components into the system.

Security

The data and records that have been entrusted to ESA due to its role under Chapter 6 of the Treaty contain business secrets and sensitive information and must not be disclosed to other businesses and individuals under any circumstances.

All ESA staff, including external contractors, have undergone security clearance, and only ESA staff have access to the premises, which the Commission provides with high-level security – including regular checks by guards.

The responsibility for hosting ESA's core IT system, NOEMI, has been transferred to the Commission's Digital Services department to align with the Commission IT security strategy and comply with related security requirements. The project follows the ITSRM2. [85] In Q4-2023, ESA launched a study of the IT security plan in collaboration with the Cybersecurity Directorate of the Digital Services department, aimed at: (i) assessing the security risks of the NOEMI system; (ii) assessing the effectiveness of security measures; and (iii) proposing additional cost-effective controls to achieve acceptable risk levels. The study is due to be completed in Q1-2024.

Communication

Because of the energy challenges, particularly in Europe, and the uncertainty about the nuclear fuel and medical radioisotopes supply chain, ESA gave numerous interviews and spoke at many conferences, not only in Europe, but also in Asia, the US and other regions. The Agency also engaged significantly with its stakeholders.

6.4. 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 related transactions every year, assessing them against globally-recognised public sector auditing standards. ECA is tasked with providing the European Parliament and the Council with an assurance statement on

85 European Commission's IT security risk management methodology.

the reliability of the annual accounts and the legality and regularity of the underlying transactions.

ESA acknowledges ECA's observations and implements all necessary corrective measures. It also takes account of any cross-cutting observations accompanying the annual report of the EU Agencies.

ECA has approved the Agency's accounts for the financial year 2022 and issued an unqualified opinion on both the accounts and the legality and regularity of revenue and expenditure transactions. [86]

However, ECA noted that ESA had systematically awarded contracts below EUR 15 000 (very low value contracts according to the Financial Regulation) without issuing corresponding evaluation reports and award decisions. ESA provided ECA with replies to this observation on 7 July 2023, and committed to provide appropriate guidance to all staff involved in procurement and financial management, including templates, to ensure that the procurement procedures are properly approved and documented.

Discharge

The European Parliament, acting on a Council Recommendation, is the discharge authority for ESA.

On 10 May 2023, the European Parliament granted ESA's Director-General discharge for the implementation of the budget for the financial year 2021. [87]

6.5. Internal control and assurance

Internal control and risk management

The Agency has an internal control framework designed to provide reasonable assurance in achieving the five objectives set out in Article 36 of the Financial Regulation.

In 2023, ESA updated its risk assessment to cover all areas of the Agency's work and its operational and administrative processes. Adjustments were introduced to align existing controls with the risks.

Management assurance

ESA conducted a 'light' self-assessment to assess the effectiveness of its internal controls. This consisted of: (i) an evaluation of the changes introduced to the pre-defined monitoring indicators; (ii) an evaluation of audit results and the state-of-play of new or outstanding recommendations; and (iii) an analysis of cases of non-compliance and exceptions.

The annual assessment for 2023 did not reveal any risks that could lead to a reservation in the annual declaration of assurance.

Based on elements 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 which accompanies this report (see Annex A).

6.6. Improving effectiveness and efficiency

In recent years, ESA has made significant progress in increasing its effectiveness and efficiency, despite its limited resources and increased workload. It particularly enhanced its monitoring of the nuclear fuel and services market and the management of nuclear fuel cycle contracts. The Agency's unwavering commitment to continuous improvement has enabled it to successfully undertake new tasks while continuing to fulfil its legal obligations.

> ESA has made significant progress in increasing its effectiveness and efficiency, despite its limited resources and increased workload.

A pivotal initiative by ESA to boost efficiency is the development of the NOEMI IT system which facilitates digital processing of nuclear supply contracts and market information, in compliance with rules on information protection. The initiation of digitally signed contracts will enable the full electronic handling of procedures, and the ongoing development of the NOEMI IT system is expected to yield further efficiency gains

86 Annex 9 and ECA Annual report on EU agencies for the financial year 2022: https://www.eca.europa.eu/en/publications/SAR-AGENCIES-2022.
87 European Parliament Decision of 10 May 2023: P9_TA(2023)0169 – Decision 2022/2114(DEC): https://oeil.secure.europarl.europa.eu/oeil/popups/printficheglobal.pdf?id=740074&l=en.

in its upcoming Phases 2 and 3. This includes the introduction of an internal workflow to streamline the handling of contract information, as well as the creation of a portal for market participants to digitally exchange contracts and data with the Agency, thereby enhancing processes and providing benefits for utilities companies and industry.

Furthermore, ESA has improved the effectiveness of its accounting and financial obligations by sharing the accounting officer role with the Translation Centre for the Bodies of the European Union. The Agency has also identified potential efficiency gains by collaborating more closely with the Commission and benefiting from its specialised support functions and corporate tools to enhance the efficiency of administrative operations, such as work-related travel, treasury and security. This will enable ESA to carry out the increasing number of tasks effectively and respond to stakeholders' expectations.

Enusa Juzbado facility

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

X

@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: https://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.

Annexes

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

(A) 2024-2033

Year	Natural uranium		Separative work	
	Gross requirements	Net requirements	Gross requirements	Net requirements
2024	11 896	10 206	10 192	8 950
2025	13 291	10 967	11 308	9 772
2026	13 479	11 557	11 238	9 504
2027	12 693	10 816	10 556	8 872
2028	12 442	10 269	10 777	8 948
2029	12 850	10 309	11 165	8 995
2030	11 626	8 874	9 964	7 546
2031	12 156	9 449	10 257	7 778
2032	12 479	9 792	10 385	7 912
2033	11 096	8 363	9 249	6 744
Total	**124 007**	**100 603**	**105 093**	**85 021**
Average	**12 401**	**10 060**	**10 509**	**8 502**

(B) Extended forecast 2034-2043

Year	Natural uranium		Separative work	
	Gross requirements	Net requirements	Gross requirements	Net requirements
2034	10 260	6 978	8 649	5 614
2035	10 770	7 549	8 973	5 993
2036	9 495	6 387	7 915	5 040
2037	10 138	7 145	8 449	5 679
2038	9 669	6 685	8 123	5 360
2039	9 766	6 687	8 200	5 443
2040	9 419	6 449	7 853	5 105
2041	10 286	7 318	8 540	5 793
2042	9 215	6 247	7 665	4 918
2043	9 816	6 846	8 156	5 407
Total	**98 835**	**68 391**	**82 522**	**54 352**
Average	**9 883**	**6 839**	**8 252**	**5 435**

Annex 2
Fuel loaded into EU-28 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
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
2022 (**)	1 602	10 993	8 340	11 724	2	10 732
2023 (**)	**1 771**	**12 672**	**9 611**	**14 578**	**7**	**12 260**

(*) Data not available. *(**) The LEU fuel loaded and feed equivalent contain Candu fuel.*

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
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	42.19	1.18
2022	101.28	41.02	(137.26)	(55.59)	76.19	30.86	1.05
2023	**115.79**	**48.16**	**149.28**	**60.46**	**103.56**	**41.95**	**1.08**

(*) 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, 2021 and 2022 the ESA U_3O_8 spot price was not calculated because there were not enough transactions (less than 3) to calculate the index.

Annex 4
Purchases of natural uranium by EU utilities, by origin, 2014-2023 (tU)

Country	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Canada	1 855	2 845	2 946	4 099	3 630	1 485	2 312	1 714	2 578	4 802
Russia	2 649	4 097	2 765	2 192	1 759	2 543	2 545	2 358	1 980	3 419
Kazakhstan	3 941	2 949	2 261	2 064	1 754	2 518	2 414	2 753	3 145	3 061
Niger	2 171	2 077	3 152	2 151	2 067	1 962	2 555	2 905	2 975	2 089
Namibia	325	385	504	923	1 046	1 234	481	5	262	549
Australia	1 994	1 910	1 896	2 091	1 909	1 851	1 671	1 860	327	372
Uzbekistan	365	526	115	348	166	612	329	0	441	271
South Africa	20	1	0	0	118	115	21	21	0	13
United States	586	343	125	193	110	0	0	0	0	4
Malawi	125	2	0	0	0	0	0	0	0	0
Ukraine	23	0	0	0	19	0	0	0	0	0
EU	397	412	220	0	18	251	64	163	17	0
Re-enriched tails	0	212	212	171	161	161	196	196	0	0
Other	299	229	130	80	80	103	4	0	0	0
HEU feed	0	0	0	0	0	0	0	0	0	0
Total	**14 751**	**15 990**	**14 325**	**14 312**	**12 835**	**12 835**	**12 592**	**11 975**	**11 724**	**14 578**

Annex 5
Use of plutonium in MOX in the EU-28 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
2022	3 007	277	197
2023	**4 787**	**427**	**300**
Grand total	**246 009**	**26 626**	**18 085**

Annex 6
EU nuclear utilities that contributed to this report

ČEZ, a.s.
EDF
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
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.
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 interest 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 2021 and 31 December 2023) 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 2022

EUROPEAN COURT OF AUDITORS
12, rue Alcide De Gasperi
1615 Luxembourg
LUXEMBOURG

Tel. +352 4398-1
Enquiries: eca.europa.eu/en/Pages/ContactForm.asp
Website: eca.europa.eu
Twitter: @EUAuditors

More information on the European Union is available on the internet (http://europa.eu).

Luxembourg: Publications Office of the European Union, 2023

PDF ISBN 978-92-847-9991-6 doi:10.2865/088 QJ-AG-23-001-EN-N

3.34. Euratom Supply Agency (ESA)

Introduction

3.34.1. The Euratom Supply Agency ('ESA'), located in Luxembourg, was established in 1958, with the adoption, by the Council of the European Atomic Energy Community, of ESA's statutes, repealed and replaced by Council Decision 2008/114/EC, Euratom. ESA's main task is to ensure that there is a regular supply of nuclear materials, in particular nuclear fuels, to EU users. It does so by managing a common supply policy based on the principle of equal access to sources of supply. ***Figure 3.34.1*** presents key figures for ESA[106].

Figure 3.34.1 – Key figures for ESA

* 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 ESA for the 2021 and 2022 financial years; staff figures provided by ESA.

Information in support of the statement of assurance

3.34.2. Our audit approach, the basis for our opinion, the responsibilities of ESA's management and of those charged with governance, and the auditor's responsibilities for the audit of the accounts and underlying transactions are described in section 3.1. The signature on page 351 forms an integral part of the opinion.

[106] More information on ESA's role and activities is available on its website: http://ec.europa.eu/euratom/index.html.

The ECA's statement of assurance provided to the European Parliament and the Council – Independent auditor's report

Opinion

3.34.3. We have audited:

(a) the accounts of the Euratom Supply Agency ("ESA"), which comprise the financial statements[107] and the reports on the implementation of ESA's budget[108] for the financial year ended 31 December 2022, 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

3.34.4. In our opinion, ESA's accounts for the year ended 31 December 2022 present fairly, in all material respects, ESA's financial position at 31 December 2022, 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.

[107] 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.

[108] The reports on the 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

3.34.5. In our opinion, the revenue underlying the accounts of ESA for the year ended 31 December 2022 is legal and regular in all material respects.

Payments

Opinion on the legality and regularity of payments underlying the accounts

3.34.6. In our opinion, the payments underlying the accounts of ESA for the year ended 31 December 2022 are legal and regular in all material respects.

3.34.7. The observations which follow do not call the ECA's opinion into question.

Observations on management and control systems

3.34.8. ESA systematically awards low-value contracts (below €15 000) without issuing corresponding evaluation reports and award decisions. This is not in line with points 30.3-30.4 of Annex I to the Financial Regulation.

289

Euratom Supply Agency (ESA)

ESA's reply

3.34.8. The Euratom Supply Agency agrees to the finding. The agency will provide appropriate guidance to all staff involved in procurement and financial management, including templates, to ensure that the procurement procedures are properly approved and documented.

Annex 10
Declaration of assurance

Ref. Ares(2024)4636956 - 27/06/2024

EURATOM SUPPLY AGENCY

The Director General

Luxembourg,
ENER.AAE/MH

DECLARATION OF ASSURANCE
AAR 2023

I, the undersigned, Michael HŰBEL, Director General of the Euratom Supply Agency since 1 May 2024,

In my capacity as authorising officer,

- Declare that the information contained in the Annual Activity Report, forming part II of the Annual 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 the declaration of assurance provided by the Director General who was in function until 30 September 2023, and the Acting Director General who was in function from 1 October 2023 to 30 April 2024 (see Annex I) and on my own judgment which is limited by the time of my appointment on 1 May 2024.

Based on the above confirm that I am not aware of anything not reported here which could harm the interests of the Euratom Supply Agency.

Electronically signed

Michael Hübel
ESA Director General

([1]) True and fair in this context means a reliable, complete and correct view on the state of affairs in the Agency

Euratom Supply Agency, 2920 Luxembourg, LUXEMBOURG – Tel. +352 43011

WebAddress
Michael.Huebel@ec.europa.eu

Electronically signed on 27/06/2024 10:11 (UTC+02) in accordance with Article 11 of Commission Decision (EU) 2021/2121

Euratom Supply Agency

DECLARATION OF ASSURANCE

I, the undersigned, Agnieszka Ewa Kaźmierczak

In my capacity as Director-General and authorising officer of the Euratom Supply Agency between 1 January and 30 September 2023

state that I have reasonable assurance that the resources for which I was accountable in that period 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 in Chapters 5 and 6 of the Annual Report of ESA for 2023 which could harm the interests of the Euratom Supply Agency.

Agnieszka Ewa Kaźmierczak

Electronically signed on 26/06/2024 18:09 (UTC+02) in accordance with Article 11 of Commission Decision (EU) 2021/2121

EURATOM SUPPLY AGENCY

Luxembourg, 25 June 2024
ENER.AAE.1/SC

DECLARATION OF ASSURANCE
AAR 2023

I, the undersigned, Stefano CICCARELLO, Acting Director-General of the Euratom Supply Agency from 1 October 2023 to 30 April 2024.

In my capacity as authorising officer during the period mentioned above

– Declare that the information contained in the Annual Activity Report, forming part II of the Annual 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.

Electronically signed

Stefano CICCARELLO

(1) True and fair in this context means a reliable, complete and correct view on the state of affairs in the Agency

Euratom Supply Agency, 2920 Luxembourg, LUXEMBOURG – Tel. +352 43011
Office: EUFO 02/389E – Tel. direct line +352 4301-36227

WebAddress
Stefano.CICCARELLO@ec.europa.eu

Electronically signed on 25/06/2024 10:19 (UTC+02) in accordance with Article 11 of Commission Decision (EU) 2021/2121

Annex 11
Work Programme 2024

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 regular and equitable supply of nuclear materials (ores, source material and special fissile material) 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 defined:

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 of nuclear materials, nuclear fuel cycle services and fuel and encourage the diversification and emergence of reliable alternative sources;
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;
5. Specific supporting objectives
6. pursue contacts with EU and international authorities, international organisations, utilities, industry and nuclear organisations to further the objectives of ESA;
7. further improve the effectiveness and efficiency of ESA's organisation and operations.

This work programme sets out the main activities to be pursued in 2024.

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 the 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;
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 relating to the provision of services in the nuclear fuel cycle, pursuant to Article 75 of the Euratom Treaty, in line with the common supply policy.

When exercising these tasks, ESA will:

- pay particular attention to transactions that would appear vulnerable to geopolitical risks, notably because of the place of origin of supplies;
- assist utilities in managing issues related to supply of nuclear fuel, including transport;
- provide information and support to stakeholders on contract issues related to the nuclear common supply policy;
- support the European Commission's nuclear materials accountancy, on request, in verifying contract data contained in prior notifications of movements of nuclear materials.

Activity II. Facilitating future supply of nuclear fuel

ESA takes responsibility for the common supply policy with a view to ensuring the security of supply in the short-, medium- and long-term. Through appropriate diversification, in line with the REPowerEU Communication and relevant political decisions, it aims to prevent excessive dependence of Community users on any single external supplier, service provider or design and to facilitate existence, where and when possible, of European supply production capacities in the interest of the EU's strategic autonomy, in particular as regards fuel design and supply. ESA actions support and complement, as appropriate, the EU policy framework and objectives related to energy security and security of supply in the nuclear sector.

To facilitate future supply, ESA will:

1. use its prerogatives under the Euratom Treaty to facilitate diversification of nuclear materials, nuclear fuel cycle services supply (conversion, enrichment, and

fuel fabrication) and fuel design in the medium and long term, as stressed and detailed in ESA's recommendations of its annual report 2021;
2. facilitate emergence of alternative sources of nuclear materials, nuclear fuel cycle services and fuel design where such sources are presently not available, in particular for VVER reactors;
3. Explore the potential development of the Small Modular Reactors (SMR) / Advanced Modular Reactors (AMR) technology to identify the indicative time scale and scope of its deployment, as well as its implication on future demand for nuclear materials and related services.

When exercising these tasks, ESA will stay in close communication with the European Commission services and the Advisory Committee and its subcommittees/working groups.

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 also contribute to the implementation of the Action Plan of the European 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. undertake measures that facilitate supply of high-enriched uranium (HEU) until full conversion of the reactors and processes using it; [1]
3. explore, assess, and propose ways to ensure future supply of high-assay low-enriched uranium (HALEU) for production of medical radioisotopes and as fuel for research reactors, based on the conclusions of the last working group report dedicated to the safety of supply of HALEU, as published by ESA in July 2022;
4. explore ways of monitoring and forecasting the supply of a wide range of radioisotopes. (1)

To exercise these tasks, ESA will also:

- monitor the needs for HEU and HALEU for the production of medical radioisotopes and for fuelling research reactors;

- 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 needs to retain 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, including by the annual survey;
2. publish the market analysis as part of its Annual Report;
3. publish and disseminate information, including through yearly natural uranium price indices, reports, studies, newsletters, timely updates on ESA's website and through the meetings of the Advisory Committee, Council's Atomic Questions Working Party and other.

ESA will also support the activities of the Advisory Committee's subcommittees/ working groups.

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.

To further its objectives, ESA will:

1. provide, its expertise and information on the nuclear market and contribute to any measures, which the Commission may wish to adopt and/or to propose to the legislator, aiming, under the current geopolitical circumstances, to consolidate security of supply for nuclear materials and services in the interest of European users;
2. cooperate with the European Commission services, in particular in order to:

    a. provide them with factual market information to take informed decisions as well as policy or legislative actions,
    b. contribute to Commission's actions in international landscape aiming at facilitating future supply,

c. mitigate risks related to transport and other issues related to the geopolitical situation,
d. facilitate or ensure future supply of high-assay low-enriched uranium (HALEU) and related services for production of medical radioisotopes and as fuel for research reactors,
e. contribute to the security of supply of a wide range of radioisotopes, in particular through supply monitoring and forecasting,
f. facilitate industry dialogue to address medical radioisotopes issues and concerns,
g. contribute to monitoring the implementation of the Euratom cooperation agreements with non-EU countries as regards trade in nuclear materials,
h. contribute, on request, for matters within its purview, to the assessment of international agreements communicated to the Commission under Article 103 of the Treaty;

3. proactively liaise with the Advisory Committee and its subcommittees/working groups in order to monitor the situation for risk factors and trends that could put at risk security of supply of nuclear materials and related services;
4. liaise with the operators and other concerned parties to encourage and facilitate diversification and other measures aimed at security of supply of nuclear materials and related services;
5. engage with medical radioisotopes supply chain stakeholders (industry, research and user organisations) in and outside the EU in order to:

   a. explore ways of monitoring and forecasting the supply of a wide range of radioisotopes, ([1])
   b. facilitate the continued supply of medical radioisotopes,
   c. assess the needs and secure the supply of HALEU;

6. 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 and to advance towards the minimisation of HEU.

ESA will also maintain regular contact with:

- international nuclear organisations such as the IAEA and the OECD NEA;

- other international players on the nuclear fuel market, including through membership of the World Nuclear Association, the World Nuclear Fuel Market and the European Nuclear Society.

Activity VI. Making ESA's internal organisation and operations more effective

ESA will continuously review its procedures 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. the progressive implementation of ESA's document management and security policy;
6. the progressive implementation of the IT system supporting the work of ESA (NOEMI – Nuclear Observatory and ESA Management of Information).

[1] as provided for in the SAMIRA Action Plan

List of tables

List of figures

GETTING IN TOUCH WITH THE EU

In person

All over the European Union there are hundreds of Europe Direct centres. You can find the address of the centre nearest you online (european-union.europa.eu/contact-eu/meet-us_en).

On the phone or in writing

Europe Direct is a service that answers your questions about the European Union. You can contact this service:

— by freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls),
— at the following standard number: +32 22999696,
— via the following form: european-union.europa.eu/contact-eu/write-us_en.

FINDING INFORMATION ABOUT THE EU

Online

Information about the European Union in all the official languages of the EU is available on the Europa website (european-union.europa.eu).

EU publications

You can view or order EU publications at op.europa.eu/en/publications. Multiple copies of free publications can be obtained by contacting Europe Direct or your local documentation centre (european-union.europa.eu/contact-eu/meet-us_en).

EU law and related documents

For access to legal information from the EU, including all EU law since 1951 in all the official language versions, go to EUR-Lex (eur-lex.europa.eu).

EU open data

The portal data.europa.eu provides access to open datasets from the EU institutions, bodies and agencies. These can be downloaded and reused for free, for both commercial and non-commercial purposes. The portal also provides access to a wealth of datasets from European countries.

ESA

Euratom Supply Agency

Publications Office of the European Union