



Annual Report 2019



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Foreword



It is my great pleasure to present the annual report of the Euratom Supply Agency for 2019.

The report looks back at a productive year in which ESA continued to carry out and shape the common supply policy for ores, source materials and special fissile materials for all users in the EU, for power and non-power uses of nuclear energy.

This year's report follows a new structure. Chapter 1 focuses on ESA's activities in 2019. Chapter 2 analyses supply and demand of nuclear materials and services in the EU and outlines ESA's recommendations related to security of supply. Chapters 3 and 4 present nuclear energy developments in the EU and the world market for nuclear fuels respectively. Chapter 5 summarises ESA's management information and gives an overview of the use of financial and human resources it has been entrusted with, while the work programme for 2020 is set out in Annex.

In ESA, we take the long-term and Community perspective on the supply of nuclear materials and fuel. In the short and medium term, the needs of EU utilities for natural uranium and enrichment services are well covered. However, ESA remains concerned about strong dependence on a single supplier for VVER fuel fabrication and its bundling with additional products and services. We recognise and encourage utilities' efforts towards diversification and will strive to facilitate the emergence of alternative fuel.

I would like to underline excellent cooperation with ESA's Advisory Committee, which provides us with a variety of perspectives on the nuclear materials and fuel market. In 2019, the working groups of the Advisory Committee delivered two flagship reports that are of great importance for the common supply policy. One of them examines possible paths to the supply of high-assay low-enriched uranium, which currently is not produced in Europe and is destined to replace high-enriched uranium in nuclear medicine applications as well as in other areas. The other evaluates the risks to the availability of nuclear fuel and the provision of electricity at affordable prices to all EU consumers.

Building on very good relations with the services of the European Commission, we are looking forward to working under the supervision of the new Commission that took office in December 2019. We hope that the procedure for approval of the new rules for balancing demand and supply can be concluded in the coming months. The new rules - replacing the ones dating back to 1960 and only partially amended in 1975 - will provide ESA and its stakeholders with an up-to-date foundation for their work.

To improve the efficiency of Agency's operations and administration, we launched a number of internal initiatives. Notably, we embarked on a much needed and ambitious project to design and develop an IT tool that will securely collect and manage data from contracts on the supply of nuclear materials and related services. NOEMI - Nuclear Observatory and ESA Management of Information - will reinforce our market monitoring capabilities.

In 2019, the Agency welcomed five new collaborators, including myself as Director General. We are full of gratitude to colleagues that have contributed to the Agency's mission and we feel re-energised with a fresh pool of expertise and ideas. I am proud to lead the team that combines motivation, competence and work ethics.

The moment I am writing these words, the Euratom Supply Agency has just celebrated 60th anniversary of its operations. We mark this occasion with reaffirmation of our commitment to serve the Euratom Community in full respect of its principles and with the spirit of continuous innovation.

Agnieszka Kaźmierczak

Director-General of the Euratom Supply Agency

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Executive Summary

The Euratom Supply Agency (ESA), established by Article 52 of the Euratom Treaty, has the exclusive right to conclude contracts relating to the supply of nuclear materials in the EU, and the right of option on nuclear materials coming from inside the Community. ESA's strategic objective is the short, medium and long-term security of supply of nuclear materials, particularly nuclear fuel, for power and non-power uses, by means of the common supply policy. ESA has a duty to monitor the market in order to identify trends likely to affect the Union's security of supply of nuclear materials and services.

Exercising its prerogatives, ESA continued concluding nuclear materials and fuel supply contracts and acknowledging notifications of contracts for small quantities of nuclear materials and of transactions related to the provision of services in the nuclear fuel cycle.

Due to the UK withdrawal from the EU and Euratom, ESA assessed in 2019 all the supply contracts in connection with the UK that it had concluded and decided to give effect to its signature anew. It also sought Commission decisions confirming authorisations previously granted by the Commission for a number of contracts where such authorisations were required.

ESA Agency strives for diversification of sources of supply for power and non-power uses. To prevent excessive dependence of Community users on any single external supplier, ESA continued to encourage efforts to diversify the supply of nuclear fuel for reactors for which appropriate alternative offers were not available. ESA engaged with international partners to facilitate security of supply of high-enriched uranium (HEU) and high-assay low-enriched uranium (HALEU), required to feed the production of medical radioisotopes and to fuel research reactors.

In line with the market monitoring obligations, ESA's Nuclear Fuel Market Observatory issued several market reports and analyses, published price indices and cooperated with international market analysis organisations. The report 'Securing the European Supply of 19.75% enriched Uranium Fuel' provides an updated view of high-assay low-enriched uranium (HALEU) needs, including potential global demand. The revised report 'Analysis of Nuclear Fuel Availability at EU Level from a Security of Supply Perspective' identifies threats and restrictions that could jeopardise the availability of nuclear fuel and the provision of electricity at affordable prices to all EU consumers.

Given the ESA's expanded market observatory role, ESA continued to coordinate activities undertaken to improve the security of supply of medical radioisotopes, notably through co-chairing the European Observatory. The Agency was actively involved in the design of the Strategic Agenda for Medical, Industrial and Research Applications of Nuclear and Radiation Technology – SAMIRA initiative.

The regular and undisrupted supply of fuel is a major concern of every operator. A large number of Europeans rely on nuclear electricity. Nuclear power plants generate a quarter of all electricity in the EU. This share rises above 50% in some countries.

This Annual Report provides overview of nuclear fuel supply and demand in the EU. Quantitative analysis shows that EU utilities are well covered until 2025 under existing contracts, in terms of both natural uranium and enrichment services. Natural uranium supplies, as well as provisions of services to the EU continued to come from diverse sources. However, the full reliance on a single supplier for VVER fuel fabrication remains a matter of concern.

ESA observes an upward evolution in uranium prices in 2019, bringing them closer to average production costs though still depressed due to the oversupply of uranium in the market, which also delays investments in key segments. While market access to conversion and enrichment services remains sufficient in the short and medium term among EU players, low level of investment puts in question long-term security of supply. The importance of attracting young graduates and skilled workers to the nuclear sector should be taken into account.

With the view of ensuring security of supply, ESA recommends that operators apply best practices in the field of security of supply risk management, including an assessment of their risk exposure and implementation of the resulting action plans to address it. Furthermore, ESA sets out a number of specific recommendations regarding contractual terms, inventories, diversity of procurement options, investment, general market and contractual behaviours.

The report further presents the overview of the Euratom activities. In 2019, special attention was given to safety, in particular with respect to long-term operation and to new safe reactor technologies, such as licensing of Small Modular Reactors (SMRs). By the same token, the Euratom research and training programme mainly sought to enhance the safety of nuclear technologies by supporting research on all aspects of nuclear safety and to advance solutions for the management and disposal of spent fuel and radioactive waste and for the decommissioning of nuclear facilities. The Euratom perspective is complemented with the overview of the major actions, events, decisions and announcements in the nuclear field in the EU Member States.

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

The Annual Report concludes with an overview of the ESA management, administration and finances. The work programme for 2020 is annexed.

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
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 ₃ O ₈	triuranium octoxide
UF ₆	uranium hexafluoride
BWR	boiling water reactor
EPR	evolutionary/European pressurised water reactor
LWR	light water reactor
NPP	nuclear power plant
PWR	pressurised water reactor
RBMK	light water graphite-moderated reactor (Russian design)
VVER	pressurised water reactor (Russian design)
kWh	kilowatt-hour
MWh	megawatt-hour (1 000 kWh)
GWh	gigawatt-hour (1 million kWh)
TWh	terawatt-hour (1 billion kWh)
MW/GW	megawatt/gigawatt
MWe/GWe	megawatt/gigawatt (electrical output)

1. ESA operations

1.1 Mandate and strategic objectives

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

The prerogatives of the Supply Agency stem from the Treaty and secondary legislation, in particular its statutes and rules. It has the exclusive right to conclude contracts relating to the supply of nuclear materials coming from inside or outside the Community, and has a right of option on nuclear materials coming from inside the Community. It also monitors transactions related to services in the nuclear fuel cycle, including by acknowledging the notifications that market players are required to submit to it, giving details of their commitments.



ESA Archives © Euratom Supply Agency

To that end, the Treaty endows ESA with legal personality and financial autonomy, enabling it to make independent decisions on matters within its remit. It operates under the supervision of the European Commission ⁽²⁾ and is assisted by its Advisory Committee, which acts as a link between ESA and producers and users in the nuclear industry ⁽³⁾.

ESA's strategic objective is the short, medium and long-term security of supply of nuclear materials, particularly nuclear fuel, for power and non-power uses, by means of the common supply policy.

1.2. Core activities

In the interest of its strategic objective, ESA pursues the following core activities:

- managing contracts related to the supply of nuclear materials and/or services in the nuclear fuel cycle, in line with the applicable provisions, for power and non-power uses;
- promoting diversification of sources of supply in the nuclear fuel cycle, as a contribution to security of supply in the medium and long term;
- observing developments in the nuclear fuel market and in relevant R&D fields;
- monitoring (and contributing to) the secure supply of medical radioisotopes;
- publishing its Annual Report and providing information including on the European and global nuclear markets;
- reaching out to stakeholders.

1.2.1. Contract management

The Supply Agency's activities in this field encompass:

- concluding nuclear materials and fuel supply contracts, pursuant to Article 52 of the Euratom Treaty;

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

2 Article 53 of the Euratom Treaty.

3 Article 13.1 of the statutes.

- acknowledging notifications of contracts for small quantities of nuclear materials, pursuant to Article 74 of the Euratom Treaty ⁽⁴⁾;
- acknowledging notifications of transactions related to the provision of services in the nuclear fuel cycle, pursuant to Article 75 of the Euratom Treaty.

Nuclear materials coming from inside the Community may be exported only with the authorisation of the Commission.

In 2019, in its Article 52 activities, ESA assigned 178 new registration references corresponding to new contracts and amendments or supplements to existing contracts.

In the same year, in its activities under Articles 75 and 74 of the Treaty, ESA assigned 139 new registration references covering transactions related to the provision of services or the supply of small quantities of nuclear materials.

Due to the UK withdrawal from the EU and Euratom, ESA assessed all the supply contracts in connection with the UK that it had concluded, and, in agreement with the Commission and the chief negotiator's services, decided to give effect to its signature anew. It also sought Commission decisions confirming authorisations previously granted by the Commission for a number of contracts where such authorisations were required. The EU commercial contracting parties were informed individually of the outcome of the assessment and of the decisions taken. ESA also informed such parties that exceptions provided for in Article 75 would continue to apply in so far as they are unaffected by the UK Withdrawal Agreement.

1.2.2. Security and diversification of the nuclear fuel supply chain

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

Diversification of supply sources – which also contributes to the viability of the domestic nuclear industry – is an important means for security of supply in the medium and long term and, as such, is strongly acknowledged by the European Energy Security Strategy ⁽⁵⁾.

Security of energy supply

ESA monitors the situation of EU producers which export nuclear material produced in the EU, as it has option rights over such material under Article 52 of the Euratom Treaty. Where



Petten UTK with cold kits © Curium

the material is exported from the EU, ESA may require the contracting parties to accept certain conditions relating to the security of supply on the EU market.

The Supply Agency has recommended that Community utilities operating nuclear power plants maintain adequate stocks of nuclear materials, cover their future requirements by entering into multiannual contracts and or diversify their sources of supply. Diversification should cover all stages of the fuel cycle.

In 2019, to prevent excessive dependence of Community users on any single external supplier, ESA continued to follow attentively, and encouraged efforts to diversify the supply of nuclear fuel for reactors for which appropriate alternative offers were not available.

In collaboration with Slovenské Elektrárne, ESA held a forum to review the conditions for possible fuel-supply diversification for VVER-440 reactors. The participating utilities and fuel fabricators explored the performance and technical characteristics of their alternative design, and economic feasibility.

ESA continued to follow up on the steps towards supply diversification of fuel for VVER-1000 reactors in Czechia and Bulgaria, as well as the medium/long-term plans of major EU fuel manufacturers in this respect.

Supply of nuclear materials for non-power uses

In line with its strategic objective, ESA continued to scrutinise security of supply of high-enriched uranium (HEU) and high-assay low-enriched uranium (HALEU), required to feed the production of medical radioisotopes and to fuel research reactors. These strategic materials are currently not produced in the Community and have to be imported from the US or the Russian Federation.

In close cooperation with the Member States concerned, ESA continued to facilitate the supply of HEU to users who still need it until their conversion to HALEU, in line with international nuclear security commitments. In 2019, in cooperation with the US and the Euratom Member States concerned, ESA reviewed progress in implementing the Memorandum of Understanding (MoU) signed with the US Department of Energy-National Nuclear Security Administration (DoE-NNSA) in 2014 on the exchange of HEU needed to supply European research reactors and medical radioisotope production facilities. The re-

4 Commission Regulation (Euratom) No 66/2006 provides details of how transactions involving small quantities of nuclear materials are handled.

5 COM(2014) 330 final, of 28.5.2014 <https://www.eesc.europa.eu/resources/docs/european-energy-security-strategy.pdf>

view covered EU quantities delivered by the US and those still required by Euratom Member States, as well as HEU quantities to be shipped and transferred to the US for downblending. The overall balance has been maintained, as envisaged by the MoU, and a significant portion of the materials identified has already been shipped to the US.

In November 2019, ESA and representatives of Member State authorities, industry and users held exploratory discussions on the subject of future HALEU supply with the US delegation led by the DoE-NNSA.

1.2.3. Market monitoring

In the interest of its Treaty missions, the Supply Agency's statutes entrust it with a market observatory role. In particular, ESA has a duty to monitor the market in order to identify trends likely to affect the Union's security of supply of nuclear materials and services. ESA has to provide the Community with expertise, information and advice on any subject connected with the operation of the nuclear market.

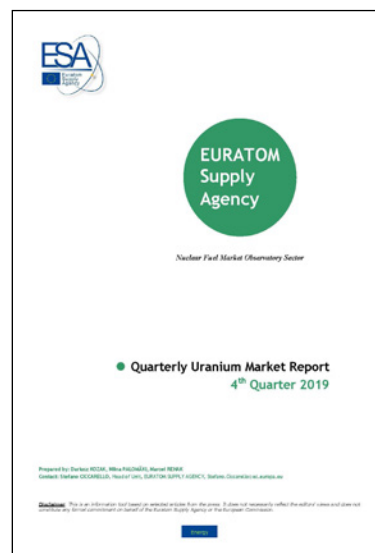
In 2019, in line with these obligations, ESA's Nuclear Fuel Market Observatory issued several market reports and analyses, published price indices and cooperated with other international market analysis organisations.

ESA's Annual Report continues to be its main reporting tool. As in previous years, ESA conducted a survey among EU nuclear power operators. The survey provided detailed analysis of the supply and demand for natural uranium, conversion and enrichment services in the EU. The Supply Agency published three price indices with calculated weighted averages of the prices paid by EU utilities within multiannual and spot contracts. Its analysis contained forecasts of future demand for uranium and enrichment services and assessed security of supply of nuclear fuel to EU utilities. ESA provided detailed analysis of future contractual coverage for natural uranium and enrichment services, diversification of supply and an analysis of EU inventories of nuclear material.



SPECT-CT scanner in use © Siemens Healthineers

In 2019, ESA issued four quarterly uranium market reports ⁽⁶⁾, which reflect global and specific Euratom developments on the nuclear market. They include general data about natural uranium supply contracts concluded by ESA or notified to it, a description of activity on the natural uranium market in the EU, and the quarterly spot price index for natural uranium whenever three or more spot contracts have been concluded.



To create greater transparency in the EU natural uranium market, reduce uncertainty and help improve security of supply, ESA regularly publishes price trends ⁽⁷⁾ and reports on its website. ESA also issues a weekly nuclear news brief for readers within the European Commission.

The ESA Nuclear Fuel Market Observatory helped assess the draft national energy and climate plans (NECP) prepared by Member States for 2021-2030. NECPs that are introduced under the Regulation on the governance of the energy union and climate action (EU/2018/1999) identify ways of achieving the EU's energy and climate targets for 2030. ESA addressed issues related to security of supply and diversification policies included in the NECPs and gave recommendations.

In 2019, the ESA Nuclear Fuel Market Observatory continued its cooperation with the International Atomic Energy Agency (IAEA) and the OECD Nuclear Energy Agency (NEA) by participating in working groups: the joint NEA/IAEA Uranium Group and the NEA Expert Group on Uranium Mining and Economic Development.

The NEA/IAEA Uranium Group is responsible for publishing the biannual report 'Uranium resources, production and demand', to which ESA contributes its analysis of EU supply and demand for nuclear fuel

6 https://ec.europa.eu/euratom/observatory_quarterly.html
7 https://ec.europa.eu/euratom/observatory_price.html

ESA presented the European perspective on security of supply at the World Nuclear Fuel Cycle conference, co-organised by the World Nuclear Association (WNA) and the Nuclear Energy Institute, and contributed in the ensuing panel discussion.

1.2.4. European Observatory on the Supply of Medical Radioisotopes

In the light of the Council Conclusions 'Towards the secure supply of radioisotopes for medical use in the EU' dated 2010⁽⁸⁾ and 2012⁽⁹⁾, ESA's market observatory role was widened in 2013 to cover aspects of the supply of medical radioisotopes in the EU.

In 2019, ESA continued to coordinate activities to improve the security of supply of Mo-99/Tc-99m and to chair, jointly with the industry association of nuclear medicine (NMEu)⁽¹⁰⁾, the European Observatory on the Supply of Medical Radioisotopes⁽¹¹⁾. In the Council Conclusions on 'Non-power nuclear and radiological technologies and applications'⁽¹²⁾ adopted in June 2019, the Council further supported "the continuing monitoring of the production chain of medical radioisotopes through the European Observatory on the Supply of Medical Radioisotopes and the ESA's efforts and actions in ensuring the secure supply of source material".

The Observatory aims to assess, monitor and support the EU supply of widely used medical radioisotopes with the focus on Molybdenum-99/Technetium-99m (Mo-99/Tc-99m). The Observatory is composed of representatives of the European Commission services, international organisations and various industry stakeholders, most of which are grouped within the NMEu. In 2019, the Observatory held two plenary meetings, in March and in September.

At the March meeting in Luxembourg, the Observatory focused on issues affecting the medical radioisotope supply chain following the withdrawal of the UK from the EU/Euratom, which could potentially lead to supply disruptions, impacting effective healthcare provision in the EU-27 and the UK. The meeting participants also addressed the possible inclusion of other novel medical radioisotopes, e.g. Lutetium-177 (Lu-177), in the scope of the Observatory. In addition, updates were provided from the NMEu, OECD/NEA and European Association of Nuclear Medicine (EANM), and on the status of the European Commission projects connected with the supply of medical radioisotopes.

At the September meeting in Amsterdam, the Observatory further discussed the impact of Brexit, preparation and possible mitigation actions to be put in place in the event of potential

disruption in the supply of medical radioisotopes. The Group also looked at the future options for producing Mo-99/Tc-99m in the EU, discussing the new infrastructure projects in the EU – JHR⁽¹³⁾, Pallas⁽¹⁴⁾, Myrrha⁽¹⁵⁾ and SMART⁽¹⁶⁾. Schedules of global research reactors, Mo-99 supply monitoring and future supply of HALEU were other topics dealt with at the meeting. Curium and NRG organised a technical visit to their facilities in Petten.

In 2019, ESA was also actively involved in designing the Strategic Agenda for Medical, Industrial and Research Applications of Nuclear and Radiation Technology ('SAMIRA', see Section 3.3.2), by participating in the dedicated Task Force and by contributing to the development of an action plan. It also played a large part in the preparation of the workshop in February 2019 that aimed to investigate the challenges and opportunities in the area, providing expertise on medical radioisotopes.

1.2.5. Annual Report

ESA's 2018 Annual Report gave an overview of its own activities and developments in the EU and world nuclear fuel markets and nuclear energy during the year. It set out ESA's findings and recommendations on the supply and demand of nuclear fuels, reflecting ESA's diversification policy and security of supply. It also discussed issues relating to the security of supply of medical radioisotopes. ESA's work programme for the following year was part of the report.

The ESA 2018 Annual Report, was published in June 2019, and is available on ESA's website⁽¹⁷⁾. The report was sent to the European Commission, the Council of the EU and the European Parliament in August 2019.



8 <https://ec.europa.eu/euratom/docs/118234.pdf>
 9 https://ec.europa.eu/euratom/docs/2012_council_radioisotopes.pdf
 10 <http://nuclearmedicineeurope.eu>
 11 https://ec.europa.eu/euratom/observatory_radioisotopes.html
 12 https://ec.europa.eu/euratom/docs/CC_non_power_2019.pdf

13 <http://www-rjh.cea.fr/index.html>
 14 <https://www.pallasreactor.com/en/>
 15 <https://myrrha.be/>
 16 https://ec.europa.eu/energy/sites/ener/files/documents/s1-3_ekollegger_ire.pdf
 17 <https://ec.europa.eu/euratom/ar/ar2018.pdf>

1.2.6. Outreach activities

Throughout 2019, ESA pursued contacts with the EU and international authorities, utilities, industry and nuclear organisations to further its objectives, engaging in continuous dialogue with suppliers, industry and utilities. It monitored market developments and EU demand. It provided advice and follow-up to ensure appropriate implementation of the common supply policy.

The Supply Agency responded to queries related to the withdrawal of the UK from the EU and Euratom submitted by individuals or undertakings with commercial relations with businesses established in the UK.

1.3. Advisory Committee

In line with ESA's statutes, the Advisory Committee ⁽¹⁸⁾ assists it in carrying out its tasks by giving opinions and providing analyses and information. The Advisory Committee also acts as a link between ESA, producers and users in the nuclear industry, and Member State governments. ESA provides the secretariat and logistical support to the Advisory Committee and its working groups.

The Advisory Committee met twice in 2019. At the first meeting on 21 March, the Committee delivered its opinions on ESA's 2018 annual report and on ESA's audited accounts for 2018. The Committee approved the revised report 'Securing the European Supply of 19.75% enriched Uranium Fuel' prepared by the Working Group on HALEU, and discussed the progress achieved by the Working Group on Prices and Security of Supply. During the meeting, the subject of how ESA handles contracts for long-term storage and/or disposal of spent fuel was discussed. The members of the Advisory Committee presented updates on developments in their countries.

The second meeting took place on 10 October. The Committee discussed a draft report, 'Analysis of Nuclear Fuel Availability at EU Level from a Security of Supply Perspective ⁽¹⁹⁾' prepared by the Working Group on Prices and Security of Supply, and subsequently endorsed it. The Committee also discussed a follow-up to the report on HALEU endorsed at the previous meeting. During the Advisory Committee meeting, members described the latest developments in their countries. The Committee took note of the updates provided on the ESA draft budget for the 2020 financial year and on ESA's work programme for 2020. The Committee also provided a favourable opinion on the estimate of ESA's revenue and expenditure for the 2021 financial year.

1.3.1. Working Group on High Assay Low Enriched Uranium

In May 2019, the Working Group issued the revised report 'Securing the European Supply of 19.75% enriched Uranium Fuel' ⁽²⁰⁾. The report provides an updated view of HALEU needs, including potential global demand.

It addresses the pressing issue of US stocks of HEU available for downblending to HALEU, since these are only sufficient to cover needs until around 2040. The long-term availability and accessibility of HALEU is a key issue, since no appropriate production facilities for HALEU exist in either the EU or the US. If there are no new initiatives, there is a risk to the future security of supply of this critically important material.

The core part of the report offers a business model to build European capacity for the production of metallic HALEU, based on three different market demand scenarios. The report concludes that building such a facility in the EU is feasible but that its economic viability would depend on certain conditions, in particular production volumes, price and financing.

It takes account of developments in recent years, specifically realistic scenarios for the conversion of HEU fuelled high-performance research reactors, the current geopolitical situation, and issues relating to the shipping and transport of HALEU.



18 <https://ec.europa.eu/euratom/committee.html>

19 https://ec.europa.eu/euratom/docs/2020_Security_report_2.pdf

20 https://ec.europa.eu/euratom/docs/ESA_HALEU_report_2019.pdf

1.3.2. Working Group on Prices and Security of Supply

In 2019, the Working Group finalised its report 'Analysis of Nuclear Fuel Availability at EU Level from a Security of Supply Perspective' ⁽²¹⁾, which was subsequently presented to the Advisory Committee in October.

This report, which is an update of the 2015 analysis, identifies threats and restrictions that could jeopardise the availability of nuclear fuel and the provision of electricity at affordable prices to all EU consumers. It identifies the top 10 risks with the potentially highest impact on security of supply. In order to provide a more accurate analysis of the different risks, this report offers a new methodology for evaluating risks, when compared with the 2015 report that took account of the duration of impact on supply.

1.4. International cooperation

ESA has long-standing and well-established relationships on nuclear energy with two major international organisations: the IAEA and the OECD NEA. In 2019, ESA continued its cooperation with both these organisations by participating in three

working groups: the joint NEA/IAEA Uranium Group ⁽²²⁾, the NEA Expert Group on Uranium Mining and Economic Development ⁽²³⁾ and the NEA former High-Level Group on the Security of Supply of Medical Radioisotopes (HLG-MR) ⁽²⁴⁾.

In July, ESA took part in the meeting of the NEA Expert Group on Uranium Mining and Economic Development, which intends to draft a report on contribution of uranium mining to economic development and its impacts on local and national economies. ESA contributed on the export and import of uranium in the context of security of supply of nuclear fuels.

The Supply Agency also represented the European Observatory on the Supply of Medical Radioisotopes at the former HLG-MR meeting held in July.

In April, ESA attended and participated in the panel discussion during the World Nuclear Fuel Cycle conference co-organised by the Nuclear Energy Institute and the WNA. In July, ESA participated in the OECD/NEA NDC meeting ⁽²⁵⁾. In September, ESA took part in the WNA Symposium ⁽²⁶⁾ and the IAEA General Conference ⁽²⁷⁾, which was an opportunity to hold bilateral meetings with the international stakeholders and Member States authorities.

21 https://ec.europa.eu/euratom/docs/2020_Security_report_2.pdf

22 <http://www.oecd-nea.org/ndd/uranium>.

23 <https://www.oecd-nea.org/ndd/groups/umed.html>.

24 <http://www.oecd-nea.org/med-radio/security/>.

25 <http://www.oecd-nea.org/ndd/ndc/>

26 <https://static.ptbl.co/static/attachments/190883/1539947593.pdf?1539947593>.

27 <https://www.iaea.org/about/policy/gc/gc62/2018-09-21>.

2. EU market

Supply and demand of nuclear material and services in the EU

This overview of nuclear fuel supply and demand in the EU is based on information provided by the utilities or their procurement organisations 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;
- evolution of inventories.

At the end of 2019, 126 commercial nuclear power reactors were operating in the EU, located in 14 Member States and managed by 18 nuclear utilities. Four reactors were under construction in France, Slovakia and Finland.

According to the latest available data published by the European Commission, the gross electricity generation from nuclear plants within the EU-28 in 2018 was stable at 827.01 TWh, which accounted for 25.3% of total EU-28 production ⁽²⁸⁾.

2.1. Fuel loaded

In 2019, 2 129 tU of fresh fuel was loaded into commercial reactors in the EU-28. It was produced using 14 335 tU of natural uranium and 416 tU of reprocessed uranium as feed, enriched with 10 880 tSW. The quantity of fresh fuel loaded was 4% (i.e. 96 tU) less than in 2018. The fuel loaded into EU re-



Fuel pellet © Euratom Supply Agency

actors had an average enrichment assay of 3.88%, 80% falling between 3.26% and 4.58%. The average tails assay was 0.23%, more than 90% falling between 0.20% and 0.26%.

MOX fuel was used in a number of reactors in France and the Netherlands. MOX fuel loaded into NPPs in the EU contained 5 241 kg Pu in 2019, a 35% decrease over the 8 080 kg Pu used in 2018. Use of MOX resulted in estimated savings of 470 tU and 331 tSW (see Annex 5).

The total amount of natural uranium included in fuel loaded into EU reactors in 2019, including natural uranium feed, reprocessed uranium and savings from MOX fuel, was 15 221 tU. Savings in natural uranium resulting from the use of MOX fuel together with reprocessed uranium give the amount of feed material (which otherwise would have to be used) coming from domestic secondary sources. All this provided about 5.8% of the EU's annual natural uranium requirements.

Table 1. Natural uranium equivalent included in fuel loaded by source in 2019

Source	Quantities (tU)	Share (%)
Uranium originating outside the EU	14 188	93.2
Indigenous sources ⁽¹⁾	1 033	6.8
Total annual requirements	15 221	100

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

2.2. Future requirements

EU utilities have estimated their gross reactor needs for natural uranium and enrichment services over the next 20 years, taking into account possible changes in national policies or regulatory requirements resulting in the construction of new units (only projects which already have a construction licence),

lifetime extensions, the early retirement of reactors, phasing-out or decommissioning. Net requirements are calculated on the basis of gross reactor requirements, minus savings resulting from planned uranium/plutonium recycling and inventory usage.

Natural uranium — average reactor requirements		
2020-2029	14 640 tU/year (gross)	12 701 tU/year (net)
2030-2039	11 327 tU/year (gross)	9 216 tU/year (net)

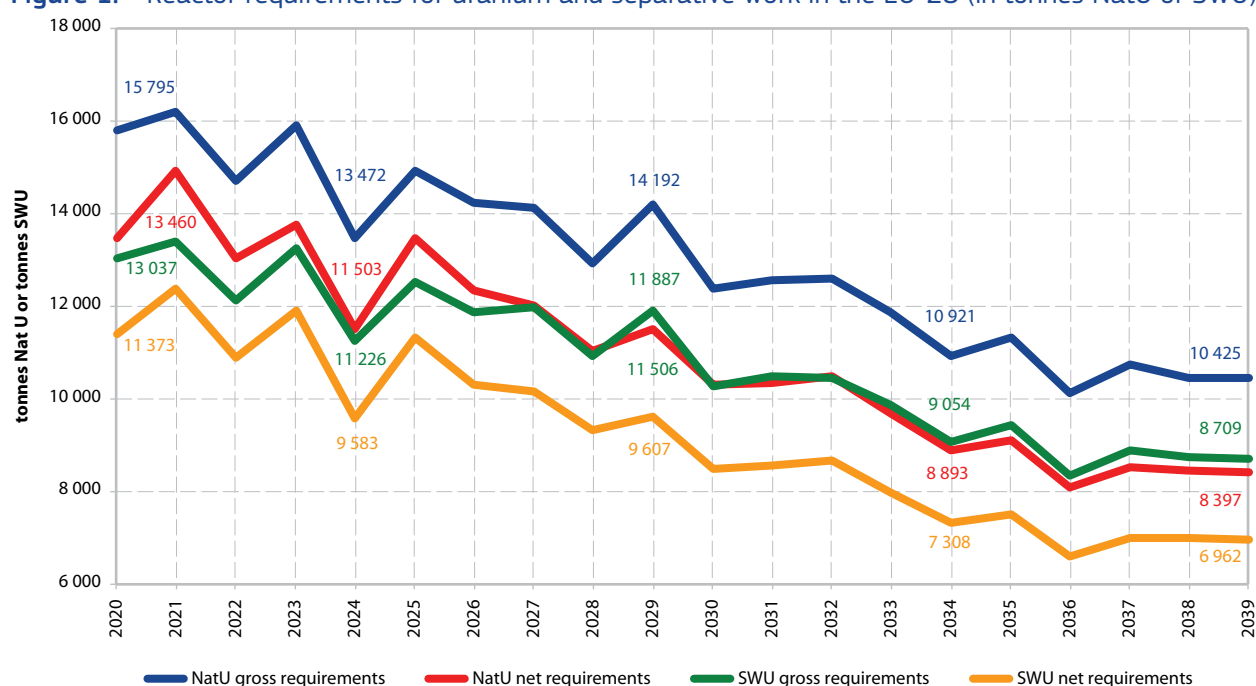
Enrichment services — average reactor requirements		
2020-2029	12 216 tSW/year (gross)	10 676 tSW/year (net)
2030-2039	9 416 tSW/year (gross)	7 600 tSW/year (net)

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).

Compared to last year's annual survey, future aggregate requirements declared by the utilities fell slightly in the first 10-year period, and more steeply in the second decade. For 2020-2029, forecasts of average gross requirements for natural uranium decreased by 5% (-775 tU), and by 5% (623 tSW) for separative work. For 2030-2039, the average gross demand for natural uranium decreased by 10% (-1 225 tU) and for enrichment services by 11% (1 127 tSW).



Worker at the Philippe Coste conversion plant at Tricastin site
© Eric Larrayadiou

Figure 1. Reactor requirements for uranium and separative work in the EU-28 (in tonnes NatU or SWU)

2.3. Supply of natural uranium

Conclusion of contracts

In 2019, ESA processed a total of 104 natural uranium contracts and amendments to contracts, of which 50 were newly

concluded and registered. Of 41 new purchase/sale contracts, 27 involved EU utilities, and the remainder were signed by EU intermediaries or producers. Table 2 gives further details of the types of supply, terms and parties involved.

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

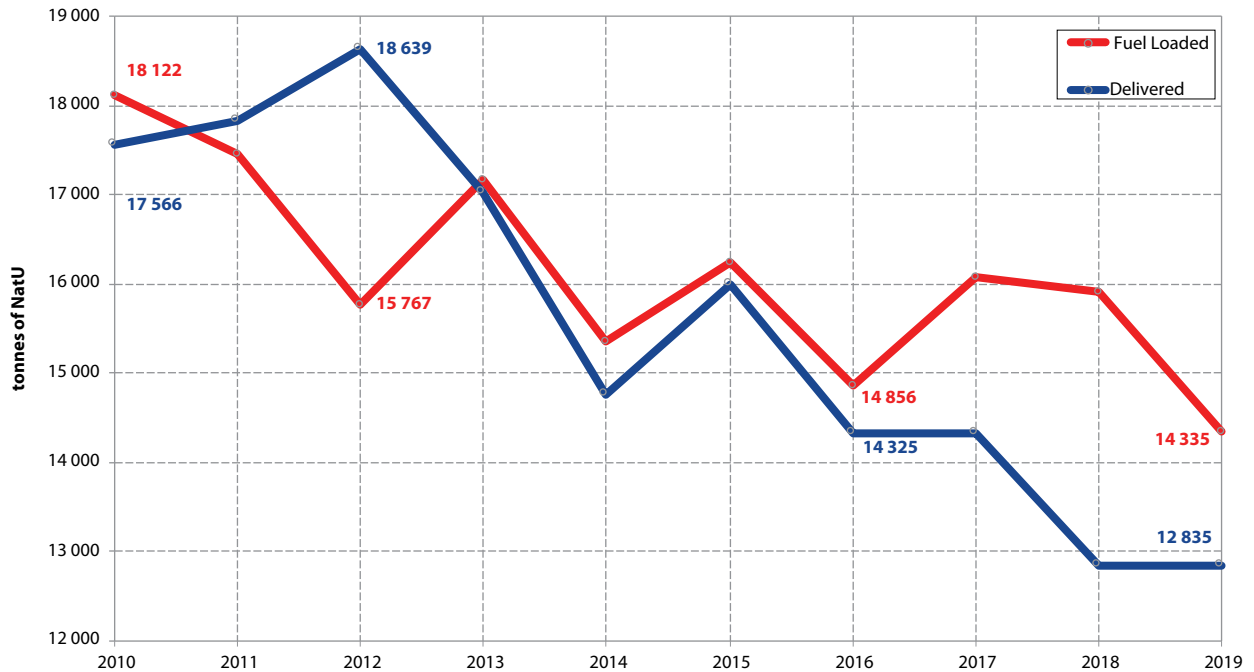
Type of contract	Number of contracts concluded in 2019	Number of contracts concluded in 2018
Purchase/sale by EU utilities/end users	27	24
— multiannual ⁽¹⁾	12	12
— spot ⁽¹⁾	15	12
Purchase/sale by EU intermediaries/producers	14	27
— multiannual	3	7
— spot	11	20
Exchanges and loans ⁽²⁾	9	10
Amendments	55	41
TOTAL ⁽³⁾	105	102

(1) Multiannual contracts are contracts providing for deliveries extending over more than 12 months, whereas spot contracts provide either for a single delivery or for deliveries over a maximum of 12 months, whatever the time between conclusion of the contract and the first delivery.

(2) This category includes exchanges of ownership and exchanges of U₃O₈ against UF₆. Exchanges of safeguard obligation codes and international exchanges of safeguard obligations are not included.

(3) Transactions for small quantities (as under Article 74 of the Euratom Treaty) are not included.

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



Volume of deliveries

The deliveries taken into account are those to EU utilities or their procurement organisations in 2019, excluding research reactors. The natural uranium equivalent contained in enriched uranium purchases, when stated, is also taken into account.

In 2019, demand for natural uranium in the EU represented approximately one quarter of global uranium requirements. EU utilities purchased a total of 12 835 tU in 162 deliveries under multiannual and spot contracts, which is the same amount as in 2018. As in previous years, supplies under multiannual contracts constituted the main source for meeting demand in the EU. Deliveries of natural uranium to EU utilities under multiannual contracts accounted for 11 604 tU (of which 11 502 tU with reported prices) or 90.4% of total deliveries, whereas the remaining 9.6% (1 231 tU) was purchased under spot contracts. On average, the quantity of natural uranium delivered was 79 tU per delivery under multiannual contracts and 76 tU per delivery under spot contracts.

Natural uranium contained in the fuel loaded into reactors in 2019 totalled 14 335 tU. For the past 6 consecutive years, EU utilities have been loading more material into reactors than they have been buying, which results in a steady decrease in inventory levels. Figure 2 shows the quantities of natural uranium feed contained in fuel loaded into EU reactors and natural uranium delivered to utilities under purchasing contracts (see Annex 2 for the corresponding table for 1980-2019).

Average delivery prices

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

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

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

Since in the global market uranium is mostly traded in US dollars, fluctuations in the EUR/USD exchange rate influence the level of the price indices calculated. The annual average ECB EUR/USD rate in 2019 stood at 1.12, which was 5% lower than in the previous year.

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

1. ESA spot U₃O₈ price: the weighted average of U₃O₈ prices paid by EU utilities for uranium delivered under spot contracts was calculated as:

EUR 55.61/kgU contained in U ₃ O ₈	25% up from EUR 44.34/kgU in 2018
USD 23.94/lb U ₃ O ₈	19% up from USD 20.14/lb U ₃ O ₈ in 2018

2. ESA multiannual U₃O₈ price: the weighted average of U₃O₈ prices paid by EU utilities for uranium delivered under multiannual contracts was calculated as:

EUR 79.43/kgU contained in U ₃ O ₈	8% up from EUR 73.74/kgU in 2018
USD 34.20/lb U ₃ O ₈	2% up from USD 33.50/lb U ₃ O ₈ in 2018

3. ESA 'MAC-3' multiannual U₃O₈ price: the weighted average of U₃O₈ prices paid by EU utilities, only for multiannual contracts which were concluded or for which the pricing method was amended in the past 3 years and under which deliveries were made, was calculated as:

EUR 80.00/kgU contained in U ₃ O ₈	8% up from EUR 74.19/kgU in 2018
USD 34.45/lb U ₃ O ₈	2% up from USD 33.70/lb U ₃ O ₈ in 2018

The ESA U₃O₈ spot price reflects the latest developments on the uranium market, as it is calculated from contracts providing either for a single delivery or for a number of deliveries over a 12-month maximum period.

In 2019, the ESA U₃O₈ spot price was **EUR 55.61/kgU** (or USD 23.94/lb U₃O₈).

The vast majority of prices fell within the range EUR 47.14–EUR 66.86/kgU (USD 20.30–USD 28.79/lb U₃O₈).

The ESA multiannual U₃O₈ price was **EUR 79.43/kgU U₃O₈** (USD 34.20/lb U₃O₈).

The multiannual prices paid varied widely, with approximately 60% (assuming a normal distribution) falling within the range EUR 51.00–EUR 110.00/kgU (USD 21.96–USD 47.37/lb U₃O₈).

Usually, multiannual prices trade at a premium to spot prices, as buyers are willing to pay a risk premium to lock in future prices. However, the ESA multiannual U₃O₈ price is not forward-looking. It is based on historical prices contracted under multiannual contracts, which are either fixed or calculated on the basis of formulas indexing mainly uranium spot prices. Spot prices are the most widely indexed prices in multiannual contracts. The ESA multiannual U₃O₈ price paid for uranium

originating in countries belonging to the Commonwealth of Independent States (namely Russia, Kazakhstan and Uzbekistan) was 21% lower than the price for uranium of non-CIS origin.

The ESA MAC-3 multiannual U₃O₈ price was **EUR 80.00/kgU U₃O₈** (USD 34.45/lb U₃O₈).

The data were spread across a wide range, with approximately 80% of prices reported as falling between EUR 47.18 and EUR 73.86/kgU (USD 20.32 to USD 31.81/lb U₃O₈).

The ESA MAC-3 index takes into account only multiannual contracts signed recently (2017–2019) or older multiannual contracts for which the uranium pricing method was amended during the same period, thus incorporating current market conditions and providing insights into the future of the nuclear market. The ESA MAC-3 multiannual U₃O₈ price paid for uranium originating in CIS countries was 32% lower than the price for uranium of non-CIS origin.

Figures 3a and 3b show the ESA average prices for natural uranium since 2010. The corresponding data are presented in Annex 3.

Figure 3a. Average prices for natural uranium delivered under spot and multiannual contracts, 2010-2019 (EUR/kgU)

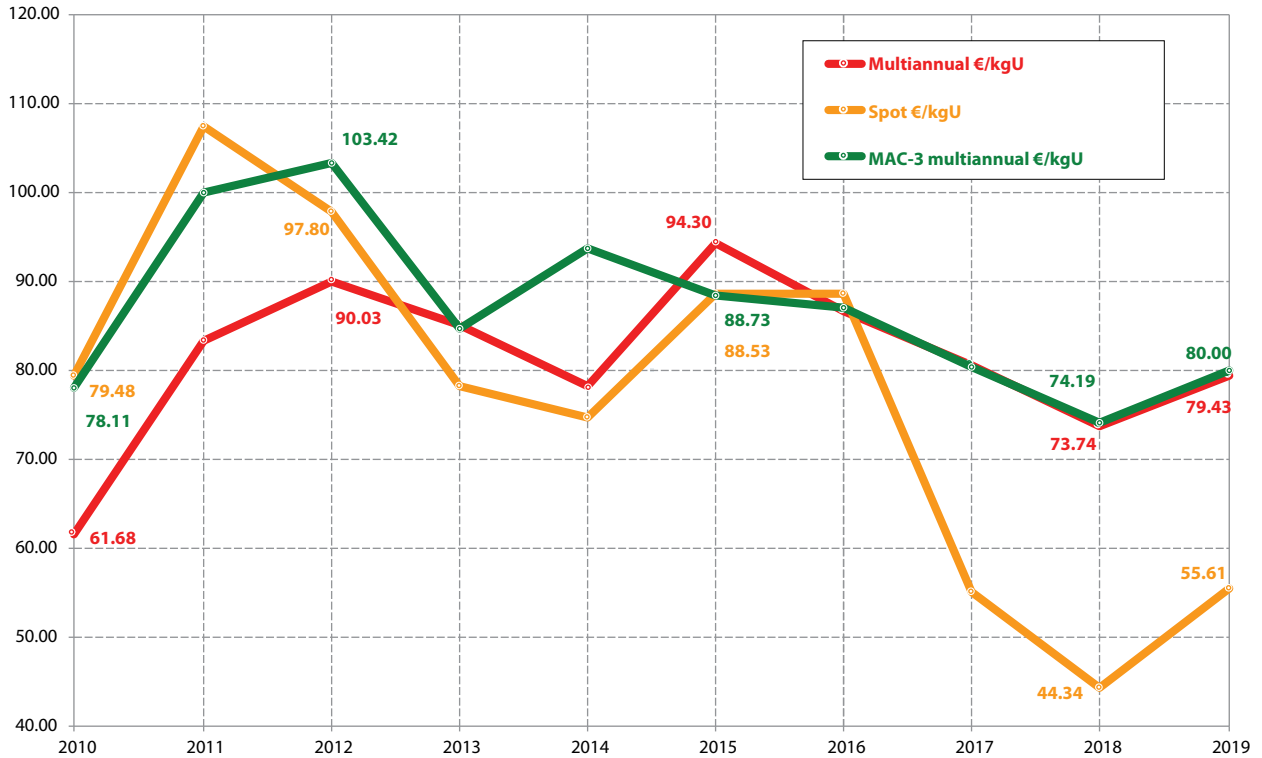
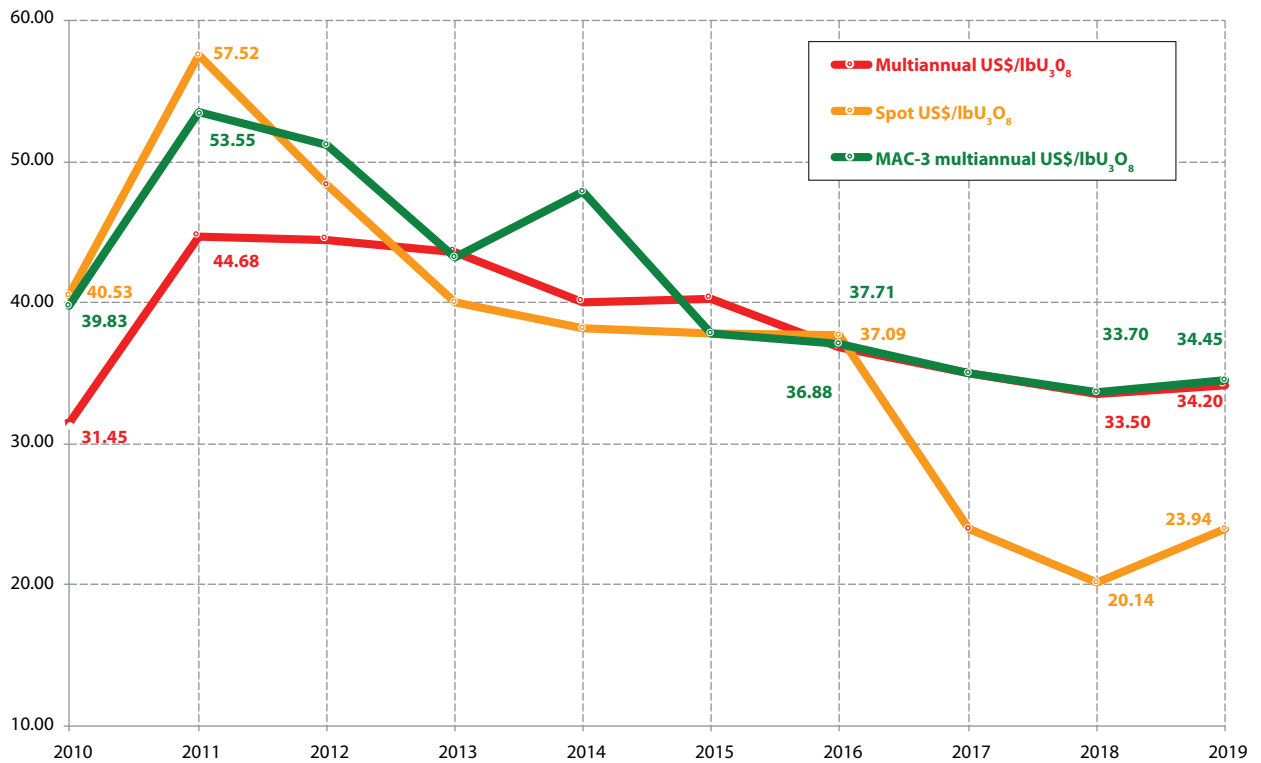


Figure 3b. Average prices for natural uranium delivered under spot and multiannual contracts, 2010-2019 (USD/lb U₃O₈)



Origins

In 2019, natural uranium supplies to the EU continued to come from diverse sources. The origin of natural uranium supplied to EU utilities has remained similar since 2018, although there have been some changes in market share.

Table 3. Origins of uranium delivered to EU utilities in 2019 (tU)

Origin	Quantity	Share (%)	Change in quantities 2019/2018 (%)
Russia	2 543	19.8%	44.6%
Kazakhstan	2 518	19.6%	43.6%
Niger	1 962	15.3%	-5.0%
Australia	1 851	14.4%	-3.0%
Canada	1 485	11.6%	-59.1%
Namibia	1 234	9.6%	18.0%
Uzbekistan	612	4.8%	269.6%
EU	251	2.0%	1310.9%
Re-enriched tails	161	1.3%	-
South Africa	115	0.9%	-2.9%
Other(1)	103	0.8%	28.9%
Total	12 835	100.0%	-

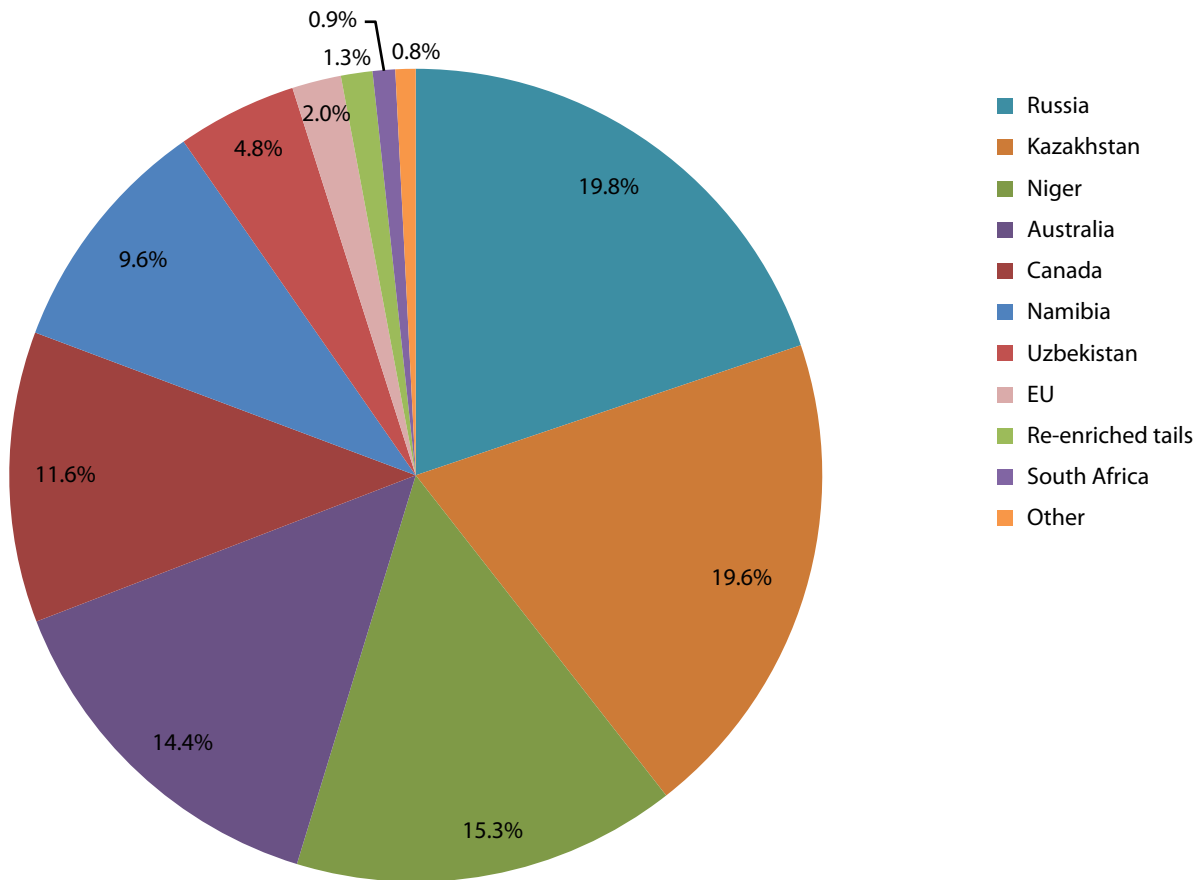
Because of rounding, totals may not add up.

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

Russia and Kazakhstan were the top two countries delivering natural uranium to the EU in 2019, providing 39.4% of the total. Deliveries from Russia include purchases of natural uranium contained in enriched uranium products (EUP). In third place, uranium mined in Niger amounted to 15.3% of the total. Uranium from Australia accounted for 14.4% of the total and from Canada 11.6%. The five big producing countries, together with sixth-placed Namibia, provided almost 90% of all natural uranium supplied to the EU.

Natural uranium produced in CIS countries accounted for 5 835 tU, or 45.5% of all natural uranium delivered to EU utilities, a 51% increase on the year before.

Deliveries of uranium from Africa increased by 2.5% to 3 311 tU, compared to 3 231 tU in 2018. Uranium mined in Africa originated in three countries – Niger, Namibia and South Africa, with Niger representing 59% of African-origin deliveries in 2019.

Figure 4. Origins of uranium delivered to EU utilities in 2019 (% share)

Because of rounding, totals may not add up.

Conversion services

During 2019, EU utilities, producers and intermediaries notified to ESA 10 new contracts on provision of conversion services and 3 amendments to already notified conversion contracts.

Under separate conversion contracts 7 970 tU were converted, which accounted for 63% of all conversion service deliveries to EU utilities. The remaining 37%, or 4 630 tU, were delivered

under contracts other than conversion contracts (purchases of natural UF_6 , EUP, bundled contracts for fuel assemblies). As regards the providers of conversion services, 32% of EU requirements were provided by Orano / Comurhex, followed by Rosatom (25%), Cameco (18%) and ConverDyn (17%).

Table 4. Provision of conversion services to EU utilities

Converter	Quantity in 2019 (tU)	Share in 2019 (%)	Quantity in 2018 (tU)	Share in 2018 (%)	Change in quantities 2019/2018 (%)
Orano (EU)	3 976	32	5 685	48	-30
Rosatom (Russia)	3 115	25	2 017	17	54
Cameco (Canada)	2 284	18	1 969	17	16
ConverDyn (US)	2 080	17	1 562	13	33
Unspecified	1 154	9	636	5	80
Total	12 600	100	11 869	100	6

Figure 6. Supply of conversion services to EU utilities by provider, 2016-2019 (tU)

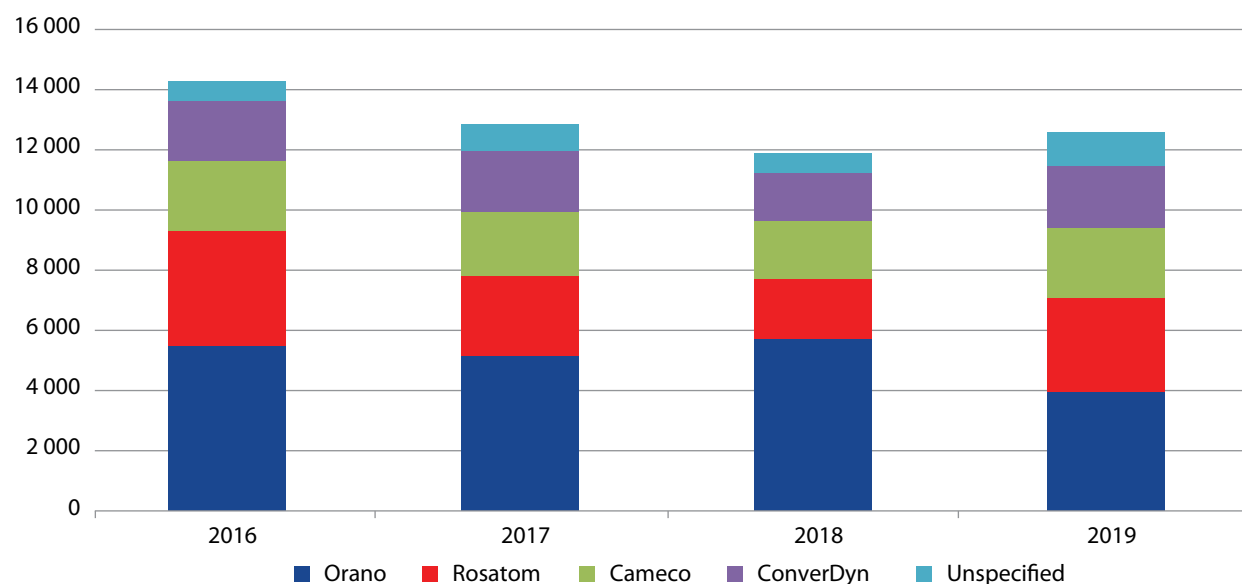


Table 5. Special fissile material contracts concluded by or notified to ESA

Type of contract	Number of contracts concluded/notifications acknowledged in 2019	Number of contracts concluded/notifications acknowledged in 2018
A. Special fissile materials		
New contracts	37	29
Purchase (by an EU utility/end user)	12	5
Sale (by an EU utility/end user)	11	3
Purchase/sale (between two EU utilities/end users)	5	7
Purchase/sale (intermediaries/producers)	6	8
Exchanges	4	6
Loans	0	0
Contract amendments	36	27
TOTAL ⁽¹⁾	73	56
B. Enrichment notifications ⁽²⁾		
New notifications	8	15
Notifications of amendments	21	18
TOTAL	29	33
Grand total	102	89

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

⁽²⁾ Contracts with primary enrichers only.

Table 6. Providers of enrichment services to EU utilities

Provider of service	Quantities in 2019 (tSW)	Share in 2019 (%)	Quantities in 2018 (tSW)	Share in 2018 (%)	Change in quantities 2019/2018 (%)
Orano-GBII and Urenco (EU)	8 764	68	7 151	66	22
Tenex/TVEL (Russia)	3 927	30	3 462	32	13
Russian blended ⁽¹⁾	160	1	286	3	-44
Other	60	1	0	-	-
TOTAL ⁽²⁾	12 912	100	10 899	100	18

⁽¹⁾ Including enriched reprocessed uranium.

⁽²⁾ Because of rounding, totals may not add up.

2.4. Special fissile material

Conclusion of contracts

Table 5 shows the aggregate number of contracts, notifications and amendments ⁽²⁹⁾ relating to special fissile materials (enrichment services, enriched uranium and plutonium) handled in 2018 and 2019 in accordance with ESA's procedures.

Deliveries of low-enriched uranium

In 2019, the enrichment services (separative work) provided to EU utilities totalled 12 912 tSW, delivered in 2 041 tonnes

of low-enriched uranium (tLEU), which contained the equivalent of 15643 tonnes of natural uranium feed. In 2019, enrichment service deliveries to EU utilities were 18% higher compared to 2018, with NPP operators opting for an average enrichment assay of 4.08% and an average tails assay of 0.22%.

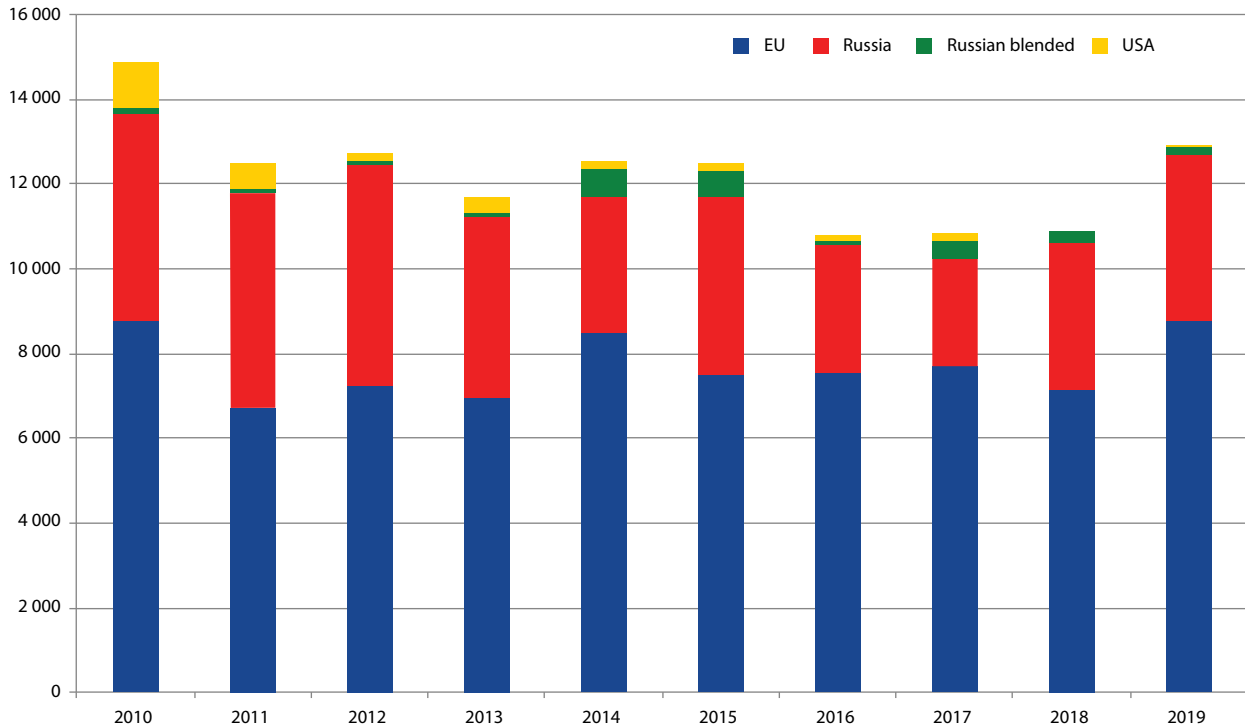
As regards the providers of enrichment services, 68% of EU requirements were met by the two European enrichers (Orano-GBII and Urenco), totalling 8 764tSW, an increase of 22% in a year-on-year comparison.

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

Deliveries of separative work from Russia (Tenex and TVEL) to EU utilities under purchasing contracts totalled 3 927 tSW, which accounts for 30% of total deliveries, a 13% increase on the year before. The aggregate total includes SWUs delivered

under contracts concluded before accession to the EU ('grandfathered' under Article 105 of the Euratom Treaty), which covered less than 4% of total EU requirements.

Figure 7. Supply of enrichment to EU utilities by provider, 2010-2019 (tSW)



Plutonium and MOX fuel

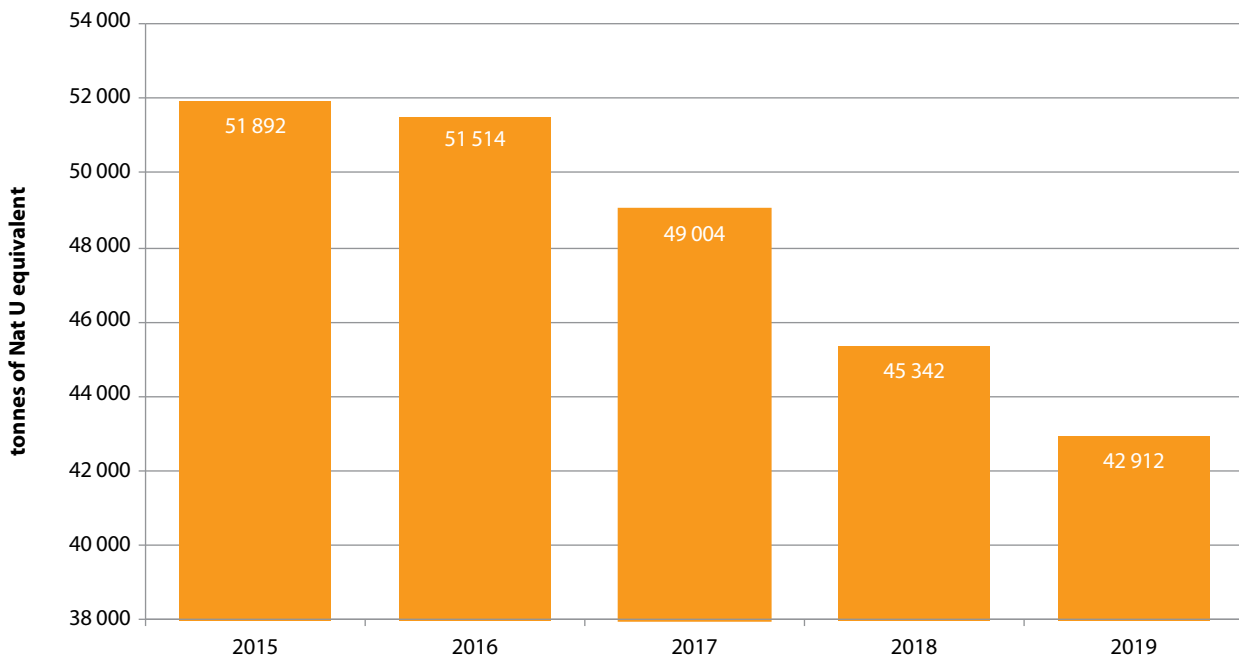
MOX fuel is produced by mixing uranium and plutonium recovered from spent fuel. Use of MOX fuel has an impact on reactor performance and safety requirements. Reactors have to be adapted for this kind of fuel and must obtain a special licence before using it. MOX fuel behaves similarly (though not identically) to the enriched uranium-based fuel used in most reactors. The main reasons for using it are the possibility of using plutonium recovered from spent fuel, non-proliferation concerns, and economic considerations. Reprocessing spent fuel and recycling recovered plutonium together with uranium in MOX fuel increases the availability of nuclear material, reduces the need for enrichment services, and contributes to the security of supply. The quantity of plutonium contained in the

MOX fuel loaded into NPPs in the EU was 5 241 kg in 2019, a 35% decrease over the 8 080 kg used in 2018.

Inventories

At the end of 2019, the natural uranium equivalent in inventories owned by EU utilities totalled 42 912 tU, a decrease of 5% from the end of 2018 and a decrease of 17% since the end of 2015. The inventories represent uranium at different stages of the nuclear fuel cycle (natural uranium, in-process for conversion, enrichment or fuel fabrication), stored at EU or other nuclear facilities.

Figure 8. Total natural uranium equivalent inventories owned by EU utilities at the end of the year, 2015-2019 (in tonnes)



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

Based on average annual EU gross uranium reactor requirements (approximately 15 500 tU per year), uranium inventories can fuel EU utilities' nuclear power reactors for 3 years on average. However, the average conceals a wide range, although all utilities keep a sufficient quantity of inventories for at least one reload.

Future contractual coverage rate

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

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

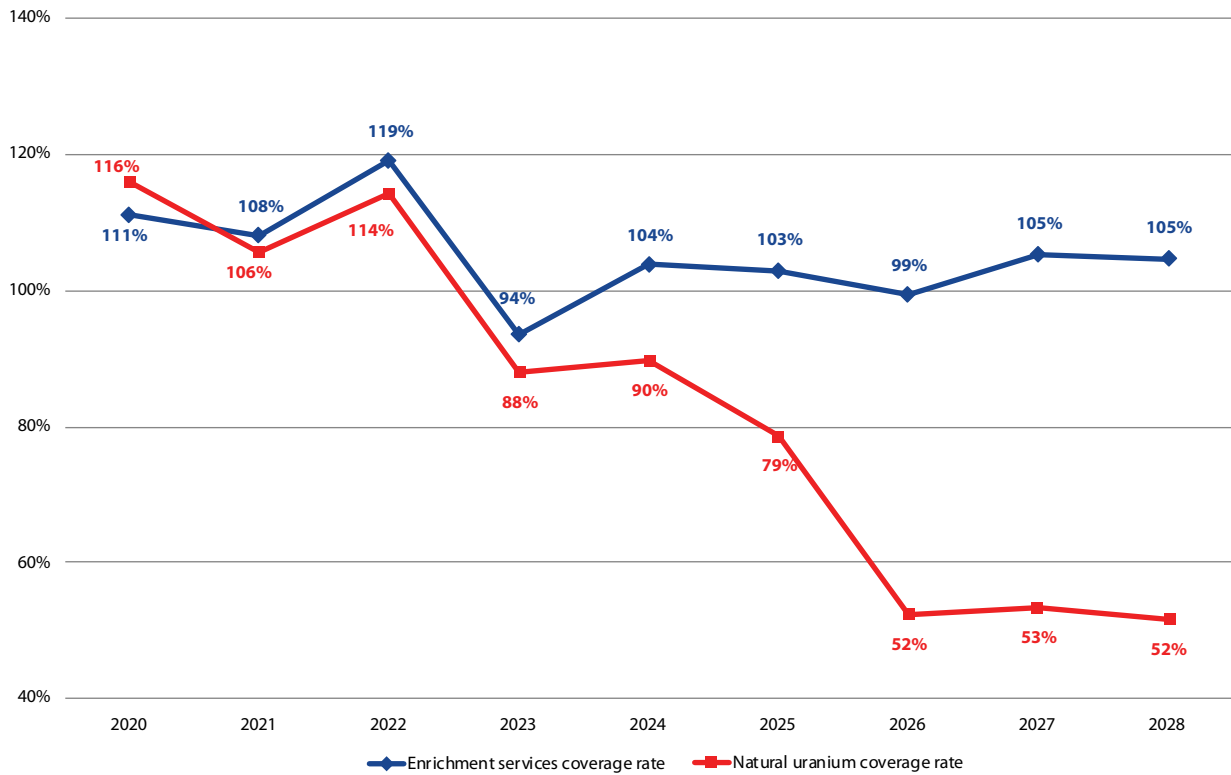
As regards net reactor requirements (the denominator), a distinction is made between demand for natural uranium and demand for enrichment services. Average net reactor requirements for 2020-2029 are estimated at 12 700 tU and 10 676 tSW per year (see table in Annex 1). ESA assumes the same quantity of requirements for conversion services as for natural uranium. A distinction is drawn between demand for conversion services covered under separate conversion contracts and other contracts, which include deliveries of natural UF₆, EUP or bundled contracts for fuel assemblies.

For natural uranium, supply is well secured from 2020 to 2025, with a contractual coverage rate of 116% in 2020 and 79% in 2025. In the long term, the uranium coverage rate drops to about 50% between 2026 and 2028.

Enrichment services supply is well secured until 2028, with a contractual coverage rate fluctuating between 94% and 119%.

Quantitative analysis shows that EU utilities are well covered until 2025, in terms of both natural uranium and enrichment services, under existing contracts. The coverage rates vary between 80% and more than 100%.

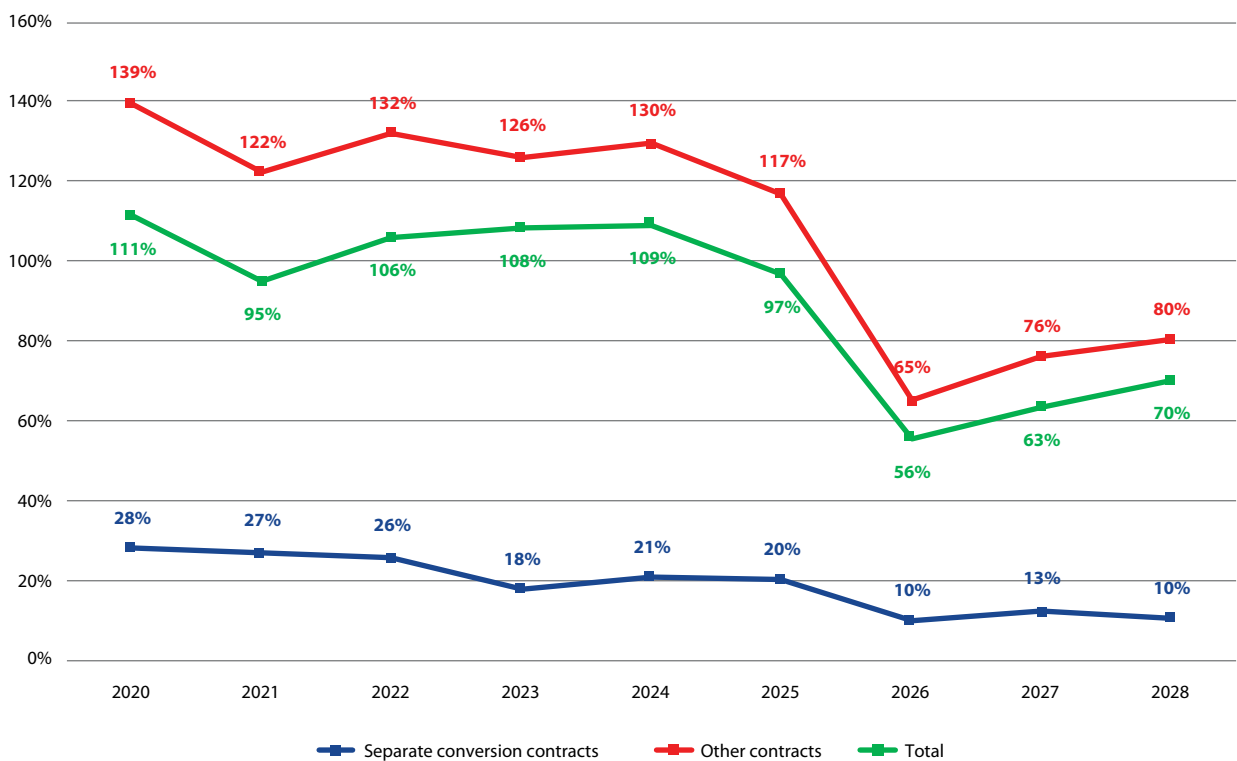
Figure 9. Coverage rate for natural uranium and enrichment services, 2020-2028 (%)



Quantitative analysis of conversion services shows that EU utilities' net reactor requirements are well covered under existing contracts, with conversion services coverage rates

above 100% until 2025. Supply is well secured until 2028, with a contractual coverage rate accounting for more than 60% in 2026-2028.

Figure 10. Coverage rate for conversion services, 2020-2028 (%)



2.5. Findings on the security of supply

To fulfil its statutory mission of identifying market trends likely to affect the security of the EU's supply of nuclear materials and services, ESA continued monitoring the EU nuclear fuel market against the world developments. ESA compiled comprehensive statistical reports on trends in the nuclear market on the basis of data related to the contracts it concluded or acknowledged, information gathered from EU utilities in the annual survey at the end of 2019, and the market data from other sources.

Diversification

Key goals for the long-term security of supply are ensuring that EU utilities have diverse sources of supply and do not depend excessively on any single supplier from a non-EU country, and maintaining the viability of the EU industry at every stage of the fuel cycle.

ESA has recommended that utilities cover most of their current and future requirements under multiannual contracts from diverse sources of supply. In line with this recommendation, deliveries of natural uranium to the EU under multiannual contracts accounted for 90% of total deliveries in 2019. As for mining origin, the relative shares of individual producer countries changed in comparison with the previous year, with Russia, Kazakhstan, Niger, Australia, Canada and Namibia together providing 90% of the natural uranium delivered to the EU. Natural uranium delivered from CIS countries accounted for 45.5% of all natural uranium delivered to EU utilities, which was a 51% increase on the year before. Deliveries of uranium from Africa increased by 2.5% to 3 311 tU, compared to 3 231 tU in 2018. In contrast, deliveries of uranium from Canada and Australia dropped in 2019. The biggest drop was in figures for deliveries from Canada, which was 59% down, followed by deliveries from Niger (-5%) and Australia (-3%). Overall, the deliveries of natural uranium to EU utilities are well diversified, but a number of utilities buy their natural uranium from only one supplier.

On diversification of sources of supply of enriched uranium to EU utilities, 68% of enrichment services were provided by the two European enrichment companies, Orano-GBII and Urenco. The remaining services were provided by Russia's Tenex/TVEL (30%) and by downblending Russian highly enriched uranium (1%). Of the 30% of SWUs of Russian origin, contracts 'grandfathered' under Article 105 of the Euratom Treaty accounted for less than 4% of total deliveries.

In 2019, total deliveries of enrichment services were 18% higher than in the previous year. The EU market relative share of the two European enrichers increased by 2 percentage points and decreased by 2 percentage points for Russian providers.

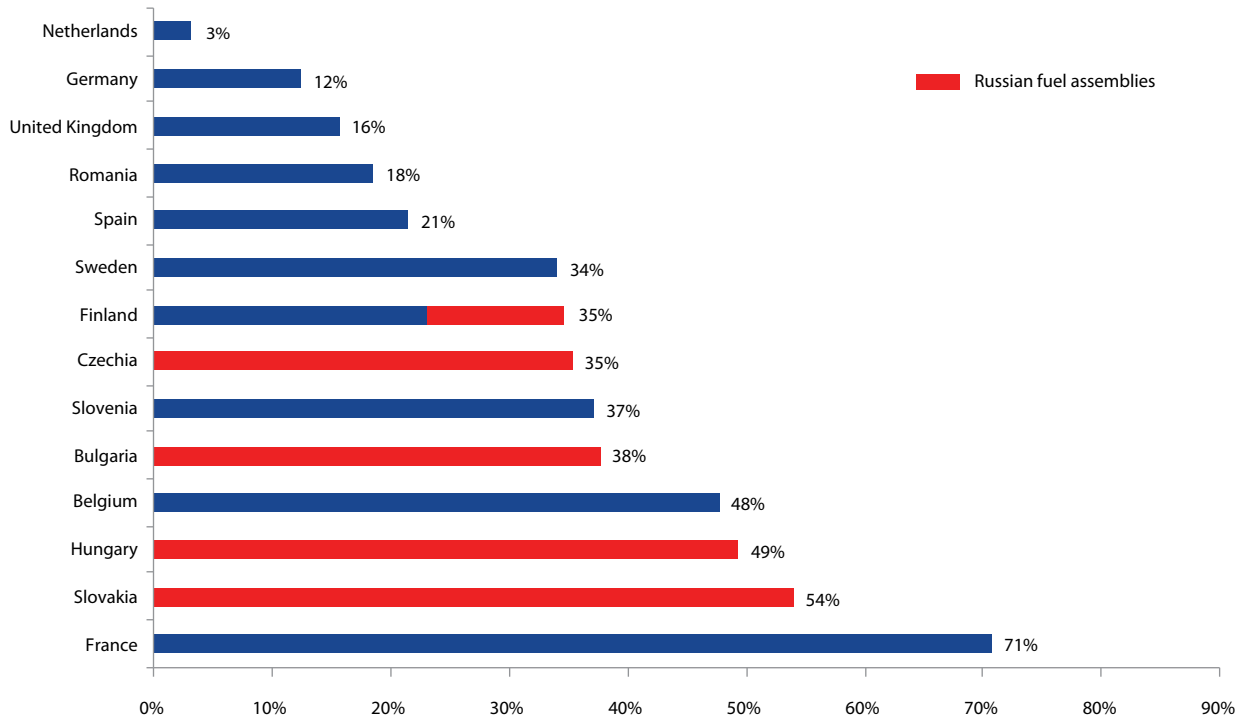
When implementing its diversification policy, ESA takes account of the positive aspects of recycling materials obtained from the reprocessing of spent fuel. Re-enriched reprocessed uranium fuel accounted for approximately 3% (416 tU) of the total feed material deliveries. MOX fuel loaded into NPPs in the EU contained 5 241 kg Pu in 2019 (a 35% decrease compared with 2018), resulting in estimated savings of 470 tU and 331 tSW.

Most EU operators of non-VVER reactors have access to at least two alternative fuel fabricators⁽³⁰⁾. The Supply Agency notes the continued dependence of VVER reactors operators on single foreign supplier for nuclear fuel. This remains a matter of concern and is considered to be a significant vulnerability, in stark contrast with the situation elsewhere.

Contrary to the situation with supplies for VVER-440 reactors, some progress towards nuclear fuel supply diversification for VVER-1000 designs is noted, followed with interest and further encouraged. (For fuel fabrication developments, see Section 4.6)

ESA welcomes efforts by VVER operators to build up strategic stocks of fuel assemblies, as a precaution.

30 In Ukraine, Energoatom has access to two VVER fuel suppliers.

Figure 11. Nuclear power share of total electricity production in the EU, 2019 (%)

Inventories

The Supply Agency also recommends that EU utilities maintain sufficient strategic inventories and use market opportunities to increase their stocks, depending on their individual circumstances. The aggregate stock level at the end of 2019 totalled 42 912 t of natural uranium equivalent, which could fuel EU utilities' nuclear power reactors for an average of 3 years. However, the average conceals a wide range, and some utilities would be wise to consider increasing their stocks.

EU fuel cycle industrial set-up

The Supply Agency notes that with few exceptions, such as conversion in the EU, insufficient investments are being made to guarantee long-term security of supply. With technology, market and energy system changes expected in the coming decade, strategic industrial investment must not be further delayed. The long-term security of nuclear fuel supply hinges on the EU nuclear industry being able to retain a skilled workforce, and further develop their technology.

ESA's Advisory Committee Working Group⁽³¹⁾ notes that lack of investment in new mines, permanent reduction of production and withdrawal from uranium exploration may lead to severe consequences in security of supply in long term. They could lead to a mismatch between demand and supply, particularly in terms of quantities, but also in terms of required regional

diversification and/or producer diversity in the utilities' supply portfolios. This makes diversification more difficult to maintain, puts pressure on prices and may result in shortage of nuclear material.

EU market and contractual set-up

The Supply Agency observes an upward evolution in uranium prices in 2019, bringing them closer to average production costs. However, it remains concerned by the oversupply of uranium in the market, which depresses prices and delays investments in key segments. Such circumstances could prevail until late in the decade, hampering necessary strategic investments.

The Supply Agency notes that market access to conversion and enrichment services remains sufficient among EU players. EU fleet requirements for the coming years are, on average, well covered by contractually secured supplies and services. ESA also finds most of the utility inventories' levels healthy. It notes a steady decrease for at least 5 consecutive years, in parallel with decreasing needs.

A limited number of utilities remains contractually bound to single suppliers, often with clauses which do not facilitate unbundling. ESA considers that contracts bundling the sale of fuel assemblies with other transactions and/or conditions or stages (uranium, conversion, enrichment, fuel fabrication) in principle represent a vulnerability in security of supply. ESA is in contact with the interested parties, seeking to address this vulnerability.

31 Analysis of Nuclear Fuel Availability at EU Level from a Security of Supply Perspective; https://ec.europa.eu/euratom/docs/2020_Security_report_2.pdf

The Supply Agency identifies transport issues as a risk in security of supply. As described in a report on security of supply by ESA's Advisory Committee Working Group ⁽³²⁾, lack of transport hubs open to nuclear shipments and lack of harmonisation and multiple regulation in transport authorisation remain problematic. Transportation of nuclear material is required at every step and has become a concern during the past years. On one hand, several European ports have followed local political decisions not to accept any new shipments of nuclear material and some shipping companies have become more reluctant to transport nuclear material.

ESA notes ongoing uncertainties relating to the future relations between the EU and the UK. These require swift clarification and appropriate contingency measures to avoid becoming a vulnerability.

2.6. Recommendations on the security of supply

After safety, the regular and undisrupted supply of fuel is a major concern of every nuclear power plant operator in the EU. A large number of Europeans rely on nuclear electricity. Nuclear power plants generate a quarter of all electricity³³. This share rises above 50% in some countries. Disruptions in supply would have dire consequences for households, hospitals and industries.

Ensuring security of supply from ore to nuclear fuel is a priority entrusted to ESA. To that end, ESA monitors the market and assesses the contracts submitted to it. It takes action as appropriate to address any vulnerabilities.

Based on its analysis, ESA concludes that, in the short and medium term, the needs of EU utilities for both natural uranium and enrichment services are well covered. However, the 100% reliance on a single supplier for VVER fuel fabrication remains a matter of concern and particularly as it can also be leveraged to supply additional products and services.

In general, ESA recommends that operators apply best practices in the field of security of supply risk management, including an assessment of their risk exposure and implementation of the resulting action plans to address it.

Considering its findings, ESA recommends as follows:

- Regarding contractual terms:
 - generally, multiannual contracts with diverse sources of supply are considered appropriate for utilities to cover most of their current and future requirements for uranium and services;

- parties engaging in contracts that bundle supplies of fuel assemblies with other transactions and/or conditions or stages of the cycle are advised to negotiate clauses expressly providing for unbundled procurement by the operator of uranium and services from other suppliers, without penalties;
- in particular for new reactors, contract terms must expressly provide for licensing and use of fuel assemblies from other suppliers, notably by providing for the disclosure of fuel compatibility data and for the testing of alternative fuel assemblies.
- Regarding inventories:
 - utilities are advised to maintain sufficient inventories of nuclear materials (including fabricated fuel) to cover future requirements, and to use market opportunities to increase them;
 - to forestall risks of shortages in the nuclear fuel supply chain, appropriate inventory levels should be maintained not only by utilities (at least one reload) but also by producers;
 - in building up inventories, due care must be paid to determination of the appropriate chemical-physical specifications and amounts, given the lead times in the fuel cycle steps involved.
- Regarding diversity of procurement options:
 - ideal security of supply means at least two alternative suppliers for each stage of the fuel cycle;
 - operators dependent on single suppliers for fuel assemblies and components are advised to step up engagement with industry and cooperation with ESA and other players to bring about alternative solutions;
 - while taking concrete actions towards emergence of alternative suppliers, utilities vulnerable at the fuel fabrication stage are advised to consider keeping strategic inventories of source materials, or even of assembled fuel, and an appropriate number of reloads per reactor, depending on their exposure to security of supply risks.

Considering its findings on the fuel cycle industrial set-up and market and contractual set-up, ESA draws attention to the following:

- Regarding investment:
 - to keep current industrial capacity, technological level and technical expertise in the fuel cycle investments would need to be stepped up;

32 Analysis of Nuclear Fuel Availability at EU Level from a Security of Supply Perspective; https://ec.europa.eu/euratom/docs/2020_Security_report_2.pdf

33 Eurostat Energy Statistics, 2018

- further efforts should be made to make the nuclear sector (power and non-power use) attractive to skilled workers and young graduates;
 - strategic industrial investments with a horizon up to 2030 should be encouraged, including in technologies, prospecting and mining development segments.
- Regarding general market and contractual behaviours:
- market players are advised to pursue market monitoring and contractual due diligence as a means to control exposure to a changing market and avert security of supply vulnerabilities;
 - ESA underlines the importance of reliable and well-timed information to allow the pursuit of security of supply policy, including timely submission of information required by the Treaty, periodical advice on any offers or requirements planned, and participation in ESA's annual survey.

ESA invites the national authorities and regulators to consider the following:

- efforts to develop a harmonised pan-European arrangement for handling cross-border transport package approvals which would be valid in each country should be continued;
- cooperation between industry, operators and regulators is vital to reduce the time to design and market of alternative nuclear fuel furthering security of supply with safety to the fore;
- particular attention should be paid to investments in new nuclear power plants to be built in the EU using non-EU technology, to ensure that these plants are not dependent only on a non-EU country for the supply of the nuclear fuel: the possibility of fuel supply diversification needs to be a condition for any new investment;
- particular care should be given to accelerating the arrival on the market of alternative fuel supply solutions for reactor designs presently bound to a single supplier from outside the EU, particularly those with operation planned for a longer perspective.

ESA would like to draw attention to:

- Article 62(2)(a) of the Euratom Treaty, whereby producers of special fissile materials (including spent in the EU nuclear fuel) from inside the Community may store them with the authorisation of ESA,
- Article 62(2)(c) of the Euratom Treaty, whereby producers of special fissile materials from inside the Community may make them available to market players in the Community under the conditions set by the provision in question;
- Article 67 of the Euratom Treaty, whereby, in principle, prices have to be determined as a result of balancing supply against demand, and national regulations of the Member States may not contravene such provisions.

3. Overview of EU developments

3.1. Euratom

3.1.1. EU nuclear energy policy

In 2019, work continued to ensure timely transposition and effective implementation of the EU legal framework on nuclear safety, responsible and safe management of spent fuel and radioactive waste, and the radiation protection of workers and the public.

The European Commission published two reports to the Council and the European Parliament on the implementation of radioactive waste and spent fuel management policies in the EU ⁽³⁴⁾.

The Nuclear Decommissioning Assistance Programmes (NDAP) in Bulgaria, Lithuania, and Slovakia continued to substantially reduce nuclear and radiation safety risks related to the reactors concerned. The NDAP reported good progress in all three sites, in particular Bohunice (Slovakia) with the dismantling of large components in the reactor building, Ignalina (Lithuania) with the steady and continuous removal of spent-fuel assemblies to a dedicated safe facility and Kozloduy (Bulgaria) with the entire completion of all dismantling activities in the turbine hall ahead of schedule.

In 2019, special attention was given to the topic of long-term operation (LTO) of nuclear power plants in the framework of the follow-up of the first Topical Peer Review (TPR) on ageing management ⁽³⁵⁾ and two major stakeholder events, namely the Prague ENEF Conference ⁽³⁶⁾ in April and the fifth ENSREG



Concrete pouring at Hinkley Point C © EDF Energy

Conference ⁽³⁷⁾ in June, to which the Directorate-General for Energy contributed. Another key topic is the availability of new safe reactor technologies, in particular in view of the future introduction and licensing of Small Modular Reactors (SMRs). The Commission hosted the first High-Level Industrial Forum on SMRs ⁽³⁸⁾, co-organised with the US Department of Energy, on 21 October in Brussels.

The Directorate-General for Energy also continued its preparatory work on a Strategic Agenda for Medical, Industrial and Research Applications of Nuclear and Radiation Technology (SAMIRA), working closely with other Commission Directorates-General and the Supply Agency. The Council of the EU, in its conclusions adopted on 6 June 2019 ⁽³⁹⁾, welcomed work undertaken so far and called upon the European Commission to prepare an action plan, with a focus on medical applications.

The Directorate-General for Energy contributed to the organisation of two workshops, one on 'Medical Radioisotopes in the Future: European Perspective' in February 2019 and one on 'Management of spent fuel and radioactive waste arising from non-energy uses of nuclear and radiation technologies' in November 2019, together with the respective Council Presidencies. The Council subsequently issued its conclusions on

34 Report from the Commission to the Council and the European Parliament on progress of implementation of Council Directive 2011/70/Euratom and an inventory of radioactive waste and spent fuel present in the Community's territory and the future prospects, COM(2019) 632 final; Report from the Commission to the European Parliament, the Council and the European Economic And Social Committee on Member States implementation of the Council Directive 2006/117/Euratom on the supervision and control of shipments of radioactive waste and spent fuel, COM(2019) 633 final.

35 <http://www.ensreg.eu/eutopical-peer-review>

36 https://ec.europa.eu/info/events/14th-european-nuclear-energy-forum-2019-apr-29_en

37 <http://www.ensreg.eu/ensreg-conferences>

38 https://ec.europa.eu/info/events/eu-us-high-level-forum-small-modular-reactors-smr-2019-oct-21_en

39 <https://data.consilium.europa.eu/doc/document/ST-10011-2019-INIT/en/pdf>

managing the radioactive waste created by non-energy nuclear technologies on 11 December 2019 ⁽⁴⁰⁾.

The Directorate-General for Energy continued to operate the ECURIE system for the exchange of urgent information in the event of a radiological emergency.

With regard to the external dimension of nuclear energy policy, the European Commission continued to actively promote the highest levels of nuclear safety also outside the EU. The main attention during the past year was the follow-up of stress tests conducted in Belarus in 2018 and in Armenia in 2017, in close cooperation with ENSREG. Civil nuclear safety cooperation with Iran under Annex III of the Joint Comprehensive Plan of Action (JCPoA) continued well, in spite of the US's withdrawal from the JCPoA. In cooperation with other European Commission services and the EEAS, the Directorate-General for Energy organised several seminars in Luxembourg and Teheran covering various aspects of nuclear safety and nuclear law, as well as an expert visit to the Kozloduy decommissioning site.

The European Commission presented the Euratom report on the implementation of the Convention on Nuclear Safety, in preparation for the eighth Review Meeting of the Contracting Parties to the Convention.

The Directorate-General for Energy also monitored and supported the interinstitutional negotiations on the proposals for the continued support to decommissioning activities in Lithuania, Bulgaria, Slovakia and the JRC facilities (EUR 1.02 billion) and to the ITER project (EUR 6.07 billion) under the new Multiannual Financial Framework (MFF) 2021-2027.

3.1.2. Euratom safeguards

Chapter 7 of the Euratom Treaty gives the Commission a legal mandate to ensure that, within the European Union, civil nuclear material is not diverted from its intended peaceful uses and that obligations derived from agreements with external parties are complied with. The Commission's Directorate-General for Energy fulfils this mandate by implementing a set of checks and verification activities known as Euratom safeguards.

In 2019, no suspicion or case of nuclear material diversion was detected. The on-site inspections and accountancy verification activities assured the public that EU nuclear operators have complied with their legal obligations and managed nuclear material appropriately.

The Commission continued to work in close cooperation with the IAEA on updating the facility-specific documents under the trilateral safeguards agreement covering the EU's 26 non-nuclear weapons states. Together with the particular safeguards

provisions issued by the European Commission, these documents are at the core of safeguard activities in the EU.

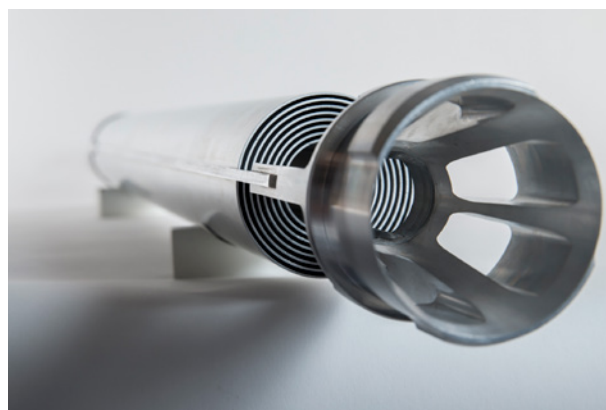
In this context, particular consideration was given to emerging challenges arising from recent changes in the nuclear industry, from developments in safeguards technology and from the changing perception of risk. The Commission addressed these challenges by adapting its safeguards approach to the new situation, among other things by promoting the use of modern tools and technologies to maximise confidence in the conclusions of inspections, and increase overall efficiency while reducing the effort required on-site. As in 2018, specific attention was paid to continuing the preparations for a smooth continuation of Euratom safeguards in the EU as well as in the UK during the transition period, but also with a view to the establishment of a reasonable safeguards system equivalent in effectiveness and coverage to the previous Euratom safeguards in the UK after its effective withdrawal from the EU and the Euratom Community.

In addition, the European Commission is strongly committed to the sharing of knowledge on safeguards through specific seminars, targeting primarily representatives from EU Member States and nuclear operators.

3.1.3. ITER

Besides fission technologies, the development of fusion as a possible future energy source was the object of much attention and effort in 2019. The construction of the ITER project continued to progress in line with the current schedule towards achieving First Plasma in 2025.

European contractors completed the walls and floors of the Tokamak Building, which will house the device. This represents a major milestone for the project, approximately 5 years after the first pouring of concrete of the building's basement. Construction is well advanced on the crane hall, which will enlarge the Tokamak building to accommodate the cranes that will move the components during assembly.



European fuel element © Framatome

40 <https://data.consilium.europa.eu/doc/document/ST-14564-2019-INIT/en/pdf>

In November 2019, at the 25th ITER Council meeting, the ITER Council reviewed the recommendations of an in-depth independent review on the IO's Assembly and Installation Strategy, carried out by independent experts. The ITER Council took note of the final report, which identified concrete actions to ensure that the assembly and installation move forward in the most efficient way possible and do not create delays or cost increases.

Euratom (represented by the Directorate-General for Energy) also advanced preparatory work with Japan on the conclusion of a Joint Declaration for the continuation of Broader Approach activities under the current bilateral agreement, which recognises the successful results and potential benefits of further cooperation for the ITER Project.

Regarding the upcoming Multiannual Financial Framework, the Commission supported the negotiations on its 2018 proposal to allocate EUR 6.07 billion to ITER, which took place under the Romanian and Finnish Presidencies in the Joint Research/Atomic Questions Working Party of the Council of the EU throughout 2019.

3.1.4. European Commission research and innovation programmes

The Euratom research and training programme 2019–2020⁽⁴¹⁾ ('the Euratom programme') is an extension of the 2014–2018 Euratom programme⁽⁴²⁾ in terms of research objectives and scope of supported activities.

Its primary aim is to enhance the safety of nuclear technologies by supporting research on all aspects of nuclear safety. Euratom-funded research also reduces the risks associated with radiation exposure from industrial or medical applications and supports emergency preparedness for accidents involving radiation. Furthermore, the Euratom programme helps advance solutions for the management and disposal of spent fuel and radioactive waste and for the decommissioning of nuclear facilities. Through actions of the Joint Research Centre, the Euratom programme provides scientific and technical support for the implementation of EU policies and strategies in the field of nuclear safeguards, non-proliferation and nuclear security. Funding is also provided for the basic research necessary for the development of reference measurements, materials and data.

In 2019 Euratom programme awarded grants to 14 research projects selected following the 2018 call for proposals. Recent examples of interesting projects include EURAD and CHANCE. The EURAD European joint research programme in the management and disposal of radioactive waste (Euratom support of EUR 32.5 million, 54% of total costs) will support implementation of the EU Directive regulating this area, taking into account the various stages of advancement of national programmes. The project gathers waste management organisations, technical support organisations and research entities from 21 Member States, Ukraine and Switzerland.

EURAD goals are to: (1) support Member States in developing and implementing their national research & development programmes for the safe long-term management of their full range of different types of radioactive waste; (2) develop and consolidate existing knowledge for the safe start of operation of the first geological disposal facilities; (3) enhance knowledge management and transfer between organisations, Member States and generations.

The project CHANCE (Characterisation of conditioned nuclear waste for its safe disposal in Europe) was awarded Euratom support of EUR 4 million (93% of total costs) grouping 9 partners from 9 Member States. Successful interim storage and final disposal of radioactive waste requires effective characterisation and quality control of the waste. CHANCE aims to address the as yet unsolved and specific issue of the characterisation of conditioned radioactive waste.

CHANCE will establish a comprehensive understanding of current characterisation methods and quality control schemes for conditioned radioactive waste in Europe.

Furthermore, CHANCE will develop, test and validate already identified and novel new techniques that will undoubtedly improve the characterisation of conditioned radioactive waste.

In the end of 2019, a fifth Euratom call for proposals was concluded by the Commission. In response to this call, 62 eligible proposals were submitted, requesting a total Euratom financial contribution of EUR 265 million. At the end of the evaluation, 31 proposals were put on a ranking list with Euratom contribution of EUR 133 million. Signature of grants will take place during 2020.

3.1.5. European Commission's Joint Research Centre activities

The Euratom research and training programme 2019–2020⁽⁴³⁾ is an extension of the 2014–2018 programme⁽⁴⁴⁾. The Commission implements the programme through direct actions, meaning research performed by the Commission's Joint Research Centre (JRC), and through indirect actions, via

41 Council Regulation (Euratom) No 2018/1563 of 15 October 2018 on the Research and Training Programme of the European Atomic Energy Community (2019–2020) complementing the Horizon 2020 Framework Programme for Research and Innovation, and repealing Regulation (Euratom) No 1314/2013 (OJ L 262/1, 19.10.2018).

42 Council Regulation (Euratom) No 1314/2013 of 16 December 2013 on the Research and Training Programme of the European Atomic Energy Community (2014–2018) complementing the Horizon 2020 Framework Programme for Research and Innovation (OJ L 347, 20.12.2013, p. 948).

43 Council Regulation (Euratom) No 2018/1563.

44 Council Regulation (Euratom) No 1314/2013.

competitive calls for proposals. The general objective of the programme is ‘to pursue nuclear research and training activities with an emphasis on the continuous improvement of nuclear safety, security and radiation protection, in particular to potentially contribute to the long-term decarbonisation of the energy system in a safe, efficient and secure way’. The programme is an integral part of Horizon 2020, the EU framework programme for research and innovation ⁽⁴⁵⁾.

The direct actions implemented by the JRC constitute an important part of the Euratom programme and pursue specific objectives covering nuclear safety, radioactive waste management, decommissioning, emergency preparedness, nuclear security, safeguards and non-proliferation, standardisation, knowledge management, education and training and support for Union policy in these fields.

The JRC 2019-2020 work programme for nuclear activities fully reflects the aforementioned objectives. It is structured in about 20 projects, and allocates 48% of its resources to nuclear safety, waste management, decommissioning and emergency preparedness, 33% to nuclear security, safeguards and non-proliferation, 12% to reference standards, nuclear science and non-energy applications, and 7% to education, training and knowledge management. To ensure that direct actions are in line with and complement the research and training needs of Member States, the JRC continuously interacts with the main research and scientific institutions in the EU, and actively participates in several technological platforms and associations.

The JRC programme contributes to the development of codes, standards and test methods for the safety analysis of nuclear reactors and provides reference data, software tools and knowledge on the behaviour of nuclear fuel in normal and accidental conditions. An example is the operation of the Clearinghouse website and database and issue of periodic reports (supported by French and German technical support organisations) to disseminate the operating experience of nuclear power plants to nuclear safety authorities (in 2019 the quarterly reports analysed 16 selected events). Using the experience gained, the JRC participated in drafting the new IAEA nuclear safety guideline on operating experience feedback for nuclear installations.

The JRC develops and produces reference materials, and is a major European provider of certified materials for determination of radioactivity in environmental samples or for determination of uranium and plutonium in support of Euratom safeguards. The JRC also provides nuclear data for nuclear energy applications; it continues its contribution to the OECD and IAEA nuclear data libraries.

The JRC also participates as a member of the consortia in the programme’s indirect actions, allowing, maintaining and



Flamanville NPP in France © Alexis Morin

further developing the JRC’s scientific excellence. The participation of the JRC in the indirect actions creates synergies between the programme’s direct and indirect actions. This can be further expanded in the next Euratom programme 2021-2025 ⁽⁴⁶⁾, exploring synergies with the Horizon Europe Programme. In this context, two pilot projects on knowledge management and on open access to the JRC research infrastructure have been launched.

To support the implementation of the EU safeguards system in an effective and efficient way, the JRC develops dedicated methods and techniques for containment and surveillance. The JRC continues to develop analytical techniques, operating the Euratom safeguards laboratories located in reprocessing plants (France and the UK), and supporting the yearly Physical Inventory Verifications in European fuel fabrication plants. Training courses for Euratom inspectors to ensure effective implementation of EU safeguards systems are also organised. Similar support is provided to the IAEA through the Commission’s safeguards support programme; five projects were finalised in 2019 and 40 are still ongoing.

The direct actions of the Euratom programme support the EU nuclear security strategies, providing training at the EU nuclear security training centre (EUSECTRA) ⁽⁴⁷⁾ and contributing to capacity enhancement in the EU Member States and neighbouring countries. In 2019, 14 one-week training courses and two additional workshops with experts from EU Member States were organised. The JRC provided nuclear forensics support to EU Member States (in 2019, samples from three incidents in two Member States were analysed). In the framework of the EU CBRN Centres of Excellence network, the JRC in collaboration with the US DoE and the Kiev Institute for Nuclear Research developed nuclear security education & training activities for participants from Georgia, Ukraine, Azerbaijan and Moldova, to improve nuclear security in the Black Sea region.

46 Proposal for a COUNCIL REGULATION establishing the Research and Training Programme of the European Atomic Energy Community for the period 2021-2025. COM/2018/437 final

47 <https://ec.europa.eu/jrc/en/european-nuclear-security-training-centre-eusectra>

The JRC provides technical support for the implementation of the Council Directive establishing a Community framework for the nuclear safety of nuclear installations, the Council Directive on responsible and safe management of spent fuel and radioactive waste and the Council Directive on the supervision and control of shipments of radioactive waste and spent fuel. JRC experts participated in the Nuclear Safety Directive's Topical Peer Review on 'Ageing management of nuclear power plants and research reactors'. In 2019, a post-Fukushima stress test peer review took place in Armenia, and the preparation of a forthcoming review in Turkey started with support from JRC experts.

The JRC also continued to assess challenges to the supply of medical radioisotopes to the European public, as well as on research for new radioisotope applications and on alternative methods of production. International partnerships have also been established to support this work, including a practical arrangement with the IAEA to enhance complementarities and synergies between the related work programmes. In the follow-up to the study on the sustainable and resilient supply of medical radioisotopes for imaging in the European market (SMER 1) conducted in 2017-2018, another survey was launched in 2019 following continued interest by the Council of the European Union, focusing on the current and emerging radionuclides applied to therapy. These activities support other EU initiatives including the important European Observatory on the Supply of Medical Radioisotopes, and the development of the EU Strategic Agenda for Medical, Industrial and Research Applications of nuclear and radiation technology (SAMIRA).

To conclude, in 2014-2019 JRC scientists published 1 083 articles and conference contributions in peer-reviewed periodicals, 304 articles in monographs or other periodicals, 26 books with JRC editorship and 20 PhD theses. The JRC organised 219 training courses for professionals and students from Member States and the Commission. In addition, it delivered reference methods and measurements, technical systems and scientific databases, opened access to its nuclear research infrastructures and offered complementary research possibilities to external users from EU Member States.

3.1.6. The UK's withdrawal from the EU

Following the notification by the United Kingdom on 29 March 2017 of its intention to withdraw from the EU and Euratom, negotiations were held under Article 50 of the Treaty on the European Union. The 'Draft Agreement on the withdrawal of the United Kingdom of Great Britain and Northern Ireland from the European Union and the European Atomic Energy Community', as agreed at negotiator level between the EU-27 and the UK on 14 November 2018, and the Joint Political Declaration of the same day setting out the framework for the future relationship between the two parties, failed to be endorsed by the UK Parliament. On 17 October 2019, an agreement was reached at negotiator level on a revised Protocol on Ireland/Northern Ireland and a revised Political Declaration, paving the way for the UK to withdraw from the EU and Euratom



Hanhikivi 1 site in Northern Finland © Fennovoima

on 31 January 2020. At the end of 2019, ratification of the Withdrawal Agreement was still due to be completed by the EU and the UK, pursuant to their respective procedures. The agreement provides for a transition period which would start on 1 February 2020 and end (unless extended) on 31 December 2020, during which (subject to certain exceptions) EU and Euratom law would remain applicable to and in the UK.

In its conclusions of 13 December 2019, the European Council reconfirmed its desire to establish a future relationship with the UK that is 'as close as possible' in line with the Political Declaration, and invited the Commission to submit to the Council a draft comprehensive mandate for a future relationship with the UK immediately after its withdrawal.

In the field of Euratom, the Joint Political Declaration stipulates that the future relationship 'should include a wide-ranging Nuclear Cooperation Agreement' between the Community and the UK on peaceful uses of nuclear energy. In the same document, the parties state that they will cooperate, through the exchange of information, on the supply of medical radioisotopes.

3.2. Country-specific developments

Several Member States published strategic energy studies or policy papers, stating new or reiterated support for nuclear energy, in some cases with the intention of starting or extending the nuclear power reactor fleet (Poland, Czechia, France, Estonia and Slovenia). Small Modular Reactor developments were also gaining attention.

At the end of 2019, a total of 126 reactors of different designs were in operation in the EU, producing 25.3% of its electricity⁽⁴⁸⁾ and 6 nuclear power reactors were under construction (see Table 7).

Table 7. Nuclear power reactors in the EU in 2019

Country	Reactors in operation (under construction)	Net capacity (MWe) (under construction)
Belgium	7	5 943
Bulgaria	2	1 926
Czechia	6	3 932
Germany (*)	7	9 515
Spain	7	7 087
France	58 (1)	62 250 (1 650)
Hungary	4	1 889
Netherlands	1	485
Romania	2	1 310
Slovenia/Croatia (**)	1	696
Slovakia	4 (2)	1 816 (942)
Finland	4 (1)	2 764 (1 720)
Sweden (***)	8	8 622
United Kingdom (****)	15 (2)	8 883 (3 440)
Total	126 (6)	117 118 (7 752)

(*) Permanent shutdown of Philippsburg-2 on 31 December 2019

(**) Croatian power company HEP owns a 50% stake in the Krško NPP in Slovenia.

(***) Permanent shutdown of Ringhals-2 on 31 December 2019

(****) Start of construction of Hinkley Point C-2 on 12 December 2019

Source: WNA and EU Member States.

Two reactors were shut down in the EU at the very end of 2019 (Philippsburg-2 in Germany and Ringhals-2 in Sweden).

Regarding ongoing and new construction projects, there was some progress. In Finland, the Olkiluoto-3 NPP received its operating licence and the first works started for Hanhikivi NPP. Hungary started the works on Paks-2 NPP and Bulgaria decided to resume Belene NPP project. Further delays were reported on projects in France and Slovakia, and Advanced Sodium Technological Reactor for Industrial Demonstration (ASTRID) was discontinued.

Nuclear power reactors in Bulgaria and Sweden received regulatory approvals for their operational lifetime extensions. The decisions depended on current and projected electricity market conditions, as well as social and political factors.

There was no tangible progress on the uranium mining projects, although there were expectations of progress in the licensing process for Terrafame in Finland. The Spanish Salamanca project faced licensing challenges during 2019.

Several Member States, in particular Belgium, Finland and Germany, are leading reflections and actions towards safe management of spent fuel and radioactive waste.

Important projects were started also in the area of non-power applications of nuclear technology (see Section 3.3.5.).

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

Belgium

Support for nuclear energy in Belgium increased. According to the survey performed for the Belgian Nuclear Forum ⁽⁴⁹⁾ in 2019, 46% of the respondents would like to keep nuclear energy a part of the electricity mix even after nuclear phase-out in 2025. This is a significant change compared to 2017, when the same survey found that only 30% of respondents were in favour.

The Belgian agency for the management of radioactive waste (Ondraf/Niras) submitted to the Federal Agency for Nuclear Control a complete licence application for the construction of a low- and intermediate-level radioactive waste disposal facility at Dessel. The estimated start of the operation is 2024.

49 <https://www.forumnucleaire.be/actus/nouvelle/tendance-principale-le-soutien-%C3%A0-l-%C3%A9nergie-nucl%C3%A9aire-augmente-aussein-de-la-population-belge>

Belgian Tractebel and Spanish Empresarios Agrupados signed the first contract (EUR 7.6 million) for the design of buildings and utilities for Myrrha research facility at the Belgian Nuclear Research Centre (SCK-CEN). Myrrha – Multi-purpose hYbrid Research Reactor for High-tech Applications – is the world's first prototype of a subcritical lead-bismuth cooled reactor driven by a particle accelerator.

A SCK-CEN initiated project called NURA focused on development of the next-generation radiopharmaceuticals. NURA will perform important research into radiopharmaceuticals to treat different types of cancer in cooperation with clinical and industrial partners. SCK-CEN and the Institute for Radioelements (IRE) announced cooperation on a project RECUMO (Recovery of Uranium from Mo-99 production) – to recycle highly radioactive residues resulting from the IRE's production of radioisotopes for medical purposes.

IRE continued its work on the SMART project – the accelerator based production of Mo-99.

Bulgaria

In March 2019 Bulgaria formally launched a call to select a strategic investor to construct two 1 000 MWe reactors at the Belene NPP. After duly assessing the received applications, five companies were shortlisted for negotiations. Negotiations will be initiated with the companies included in the shortlist to structure the Belene NPP project.

Under an agreement signed with Kozloduy nuclear power plant (KNPP), Westinghouse Electric Sweden is to provide technical and economic justification for the potential licensing and use of its fuel at the KNPP.

The Bulgarian Ministry of Energy and the KNPP committed to pursuing the ambitious fuel diversification programme. With the engagement of all parties, the licensing procedure considering fuel from alternative supplier would start in 2020.

In 2019, KNPP unit 6 operational licence was extended for another 10 years. The unit followed unit 5 (both VVER-1000), the operational licence of which was extended for a 10-year period in 2017. The units are now authorised to run until 2029 and 2027 respectively.

Czechia

Aiming to take a major role in fulfilling Czechia's 2030 European Union climate change commitments, ČEZ announced at the end of May its new strategy relating to the country's domestic power market. The main priorities listed include maintaining at high standards the existing nuclear capacity and adding new nuclear units, as well as launching renewable investments in the country and investing in digitalisation and delocalised energy initiatives and energy services across the region.

The discussion about new nuclear sources, additional to the already known plans for Dukovany NPP extension, will con-

tinue in the next 5 years, as Czechia needs more reactors in longer term, according to the Deputy Prime Minister. Based on the data in the mid-term adequacy forecast report published in October by the transmission system operator ČEPS, Czechia risks becoming dependent on electricity imports by 2030 due to the phase-out coal.

With respect to nuclear fuel used at Temelín NPP after first loading of a new advanced design of current supplier's fuel in 2018, six lead test assemblies designed and manufactured by Westinghouse Electric Sweden AB were licensed and loaded in 2019.

Estonia

As part of the national plan to establish carbon-free energy production in the Baltic region, Fermi Energia of Estonia and Moltex Energy signed in early 2019 a MoU stating their intention to work together on a Moltex advanced reactor and the development of a suitable licensing regime.

In summer 2019 a feasibility study on the suitability of Small Modular Reactors for Estonia's electricity supply and climate goals beyond 2030 was launched. Later in the year, Fermi Energia also signed a MoU with GE Hitachi Nuclear Energy to cooperate on potential deployment of a SMR in Estonia. The SMR under consideration is the Hitachi BWRX-300 reactor.

Finland

Finland has stated its aim of carbon neutrality by 2035, and would welcome lifetime extensions of existing reactors, with the support of STUK (the Radiation and Nuclear Safety Authority). Production of electricity and heat must be almost emission-free by the end of the 2030s, driven by the removal of energy tax relief for heavy industry and the introduction of tax benefits to purchase heat pumps, offshore wind turbines and electricity storage systems.

Early in 2019, the Finnish government granted the Olkiluoto-3 EPR its operating licence, the first new power reactor licence issued in Finland in 40 years. The licence is a key step towards finally putting the 1 600-MW EPR into commercial operation in 2021.

Manufacturing of main components for Hanhikivi NPP started in autumn when GE Steam Power begun manufacturing the turbine generator for the unit. Forging of the generator rotor is being done at Japan Steel Works Ltd's facilities in Japan. Hanhikivi-1 is a VVER-1200 reactor of Russian design, due to start commercial operation in 2028.

A EUR 17 million contract was awarded by the Finnish nuclear waste management company Posiva to the construction company YIT for the second phase of excavation works for final disposal facility Onkalo in Olkiluoto. The work on two central and five deposition tunnels started at the end of 2019, and will last for around 2 1/2 years.

By September, Posiva had laid the foundation stone for the spent fuel encapsulation plant to be built in connection to the final disposal facility in Olkiluoto. The cost estimate for both the repository and the encapsulation plant is about EUR 500 million.

Finnish Fortum Oyj is acquiring a majority share of German Uniper SE. Fortum signed an agreement to buy a 20.5% stake in Uniper for EUR 2.3 billion, giving it majority ownership. Uniper, spun off from E.ON SE in 2016, runs conventional and nuclear power plants in Germany, Sweden, and the UK. The transaction is subject to regulatory approvals in Russia and the US.

France

In early 2019, the French government published its multiannual energy plan. Known by its French initials PPE, this energy sector roadmap includes details on how nuclear energy's contribution to the power mix will decline over the coming years as reactors are shut down. The PPE indicates that by 2035, nuclear energy's share in the French electricity mix will drop to 50%, compared to 75% today. This led to the presentation in spring 2019 of a draft law on climate and energy, which includes the objective of net zero emissions by 2050, indicating that 14 existing reactors will need to close between 2020 and 2035.

In mid-2019, France's Atomic Energy Commission (CEA) decided to discontinue the development of ASTRID. Due to the current energy market situation no development of generation IV reactors is being planned for the first half of the century.

Later in the year, CEA, Électricité de France (EDF), the Naval Group and TechnicAtome jointly unveiled a new SMR design, NUWARD, with a 300-400 MWe capacity. The partners are open to international cooperation and have already had discussions with Westinghouse on potential cooperation.

Orano laid the cornerstone of the Innovation Center for Extractive Metallurgy (CIME) at Bessines in France. CIME develops scientific and technical solutions for its customers in the fields of industrial recycling, health, minerals and ores processing. It will also extend metals recovery activities outside the group. The new building, which is due for completion in 2021, represents an investment of EUR 30 million, with 80% of sub-contracted services being carried out by local and regional companies.

Orano is in the final stage of increasing to 37 000 tonnes the storage capacity for uranium ores on its Malvési conversion site. The finalisation of this project marks completion of the modernisation of the sole European conversion facility that converts any type of concentrates regardless of origin.

Fuel loading at Flamanville-3 is being delayed until the end of 2022, due to the weld repairs, delaying operation until early 2023. The repairs required by French regulator ASN in June

2019 will add EUR 1.5 billion to the cost of the construction, coming to the current total of EUR 12.4 billion.

As requested in the PPE, EDF, with the help of all the players in the French nuclear sector, is committed to gathering by mid-2021 the economic and industrial information needed to decide the launching of a nuclear new build programme in France. EDF and Framatome are developing an optimised EPR model, called EPR 2, based on the experience accumulated on EPR construction and current fleet operation.

France intends to extend the use of MOX fuel to its 1 300 MW light-water reactors and maintains its objective of achieving a complete closed fuel cycle.

Framatome announced at year-end that it had signed a cooperation agreement with CEA and the Japanese organisations (Japan Atomic Energy Agency, Mitsubishi Heavy Industries, and Mitsubishi FBR Systems Inc.) on the development of fast neutron reactors. This agreement follows the good cooperation of the parties on the ASTRID programme.

In December, EDF unveiled a plan called 'excell' that 'will drive the nuclear industry to achieve the highest standards of craftsmanship, quality and excellence'. The plan focuses on three major objectives: improvement of manufacturing quality; boosting skills; and tighter governance of nuclear projects. The plan reserves EUR 100 million for 2020-2021.

The Spanish manufacturer Equipos Nucleares, S.A., S.M.E. (ENSA) completed, in 2019, the manufacture of three heat exchangers for the primary circuit of the Jules Horowitz Reactor (JHR), which were installed in early 2020.

Germany

Germany is sticking to its 2022 nuclear phase-out. Early in 2019, EnBW declared that it planned to invest in building nuclear waste processing centres at its Neckarwestheim and Philippsburg NPPs. Its 1 402 MWe Philippsburg 2 unit was shut down permanently on 31 December 2019, leaving just six commercial nuclear plants still operating in Germany.

In December 2019, the research neutron source FRM II in Garching, Munich received the fresh fuel elements from France, preparing for a restart of operations in January 2020⁽⁵⁰⁾.

On 1 January 2019, ownership and operation of the interim storage facilities for high-level radioactive waste in Ahaus and Gorleben as well as the corresponding facilities at the sites of the German nuclear power plants were transferred to the state-owned Company for Interim Storage (BGZ). The utilities are responsible for the proper packaging of the high-level waste before it is accepted by and transferred to BGZ for storage. The transfer of the interim storage facilities for low and intermediate-level waste is scheduled for 2020.

50 () FRM II resumed its operation on 14 January 2020

Hungary

In mid-2019, Hungary published its national energy and climate change plan, outlining the country's plans to reduce its greenhouse gas emissions. The long-term energy strategy emphasises the importance of nuclear energy to decarbonise the energy sector.

Also in the first half of 2019, the construction of the first buildings of Paks II NPP began. Paks II will host two new VVER-1200 reactors (Units 5 & 6).

Italy

Sogin (the Italian state-owned company responsible for the decommissioning of NPPs and radioactive waste management) and the European Commission's JRC signed the deed for the definitive transfer of the Ispra-1 reactor, located inside the JRC site in Ispra. The deed transfers the ownership of the plant to Sogin, which will take the responsibility for the dismantling of the reactor.

Lithuania

In December, the Lithuanian Parliament amended the Law on the necessary measures of protection against the threats posed by unsafe nuclear power plants in third countries. Under the amendments, imports of electricity from a non-EU country operating a nuclear power plant that is recognised as unsafe pose a threat to Lithuania's national security, and companies will not be granted a permit to import electricity from such a country. In the 2017 law, the Lithuanian Parliament had declared the Belarusian Ostrovets nuclear plant unsafe and a threat to Lithuania's national security, environment and public health.

Netherlands

According to the terms of a contract signed with Terrestrial Energy, the Nuclear Research and Consultancy Group (NRG) will provide expert technical services to support 'in-core' materials testing, including graphite, for key components of Terrestrial Energy's Integral Molten Salt Reactor power plant in the High-Flux Reactor at Petten and the development of its generation IV plant. NRG's services include technical advice and in-process and post-irradiation examinations and evaluations of the test materials. The work on the Pallas research reactor project is moving forward.

The Advancing Nuclear Medicine consortium, led by NRG, received a EUR 6.8 million subsidy to develop the FIELD-LAB, intended to accelerate the development and introduction of new radiopharmaceuticals.

Poland

The results of a survey ⁽⁵¹⁾ show that support for the construction of Poland's first NPP remains high among residents in the three areas under consideration for hosting the facility.

'Poland's energy policy until 2040 – strategy for the development of the fuel and energy sector' was updated in November. The draft document, which took account of feedback from social consultations, assumes the launch of nuclear energy in 2033 (6 GWh by 2040).

The Polish government seeks to secure funds (USD 60 billion) to finance the construction of its six reactors and is looking for an minority investor to operate them. Financing is expected to be agreed next year for the first reactor.

The site selection process for a new low and intermediate-level waste repository is under development.

The consortium led by the National Centre for Nuclear Research ⁽⁵²⁾ initiated a project to develop the HTGR reactor in cooperation with Japan. The reactor is intended primarily for the production of heat and hydrogen for industry

Romania

In early 2019, NuScale Power and the Societatea Nationala Nuclearelectrica SA signed a MoU to exchange business and technical information in order to evaluate the development, licensing and construction of a NuScale SMR plant in Romania. NuScale has already signed agreements to explore deployment of its SMR technology in Canada and Jordan.

A MoU concerning strategic civil nuclear cooperation was signed in the autumn by the US and Romania. The MoU aims to develop Romania's civil nuclear programme and supports the energy security goals of both countries.

The European Commission continued its investigation into the compatibility of Romanian State aid in favour of the National Uranium Company (CNU) with the European Union rules on State aid. The investigation started in 2018, and the Commission decision on the subject was issued in the first quarter of 2020.

Slovakia

The Mochovce 3 NPP Pre-Operational Safety Review Team mission was completed at the end of 2019. According to the IAEA, 'the team of experts observed a commitment to safety by the operator and identified a few good performances to be globally shared with the nuclear industry, including implementation of a novel safety system to cool the reactor even when

51 <https://world-nuclear-news.org/Articles/Local-support-for-construction-of-Polish-plant>

52 <https://scienceinpoland.pap.pl/node/4365>

shutdown; an online tool to support event classification and prognosis, in the event of emergencies; and an effective way of communicating with external organisations and interested parties to improve the awareness of nuclear power'. Mochovce 3 fuel loading is expected in 2020.

Slovenia

In mid-2019, the Prime Minister announced that the government is supporting the plans to build a new nuclear reactor. The current reactor is a 696 MWe PWR jointly owned with Croatia, with an operating licence until 2023.

A lifetime extension was approved in 2012 by the Slovenian Nuclear Safety Administration until 2043. The operating licence is renewed every 10 years in a periodic safety review process set out in by national regulations.

The national plan is to build a second unit, with construction starting in 2027. The second unit would satisfy the increasing electricity demand and provide further decarbonisation of the electricity sector in the country.

The important role of energy independence and decarbonisation will be resolved by investments in energy mixture between nuclear and renewables.

Spain

February 2019 saw the publication of the draft national integrated energy and climate plan for 2021–2030, which is the national strategic planning tool that integrates energy and climate policy and reflects Spain's contribution to achieving the objectives established within the European Union. The plan, updated in early 2020, sets out forecasts for the evolution of nuclear energy's contribution to the energy mix, and contains plans for an orderly and staggered closure of Spain's nuclear power stations in 2025–2035.

Based on this plan, in March 2019 the owners of the Spanish nuclear power plants and ENRESA (Empresa Nacional de Residuos Radiactivos, the Spanish Radioactive Waste Company) signed a Protocol establishing an orderly closure schedule for the nuclear plants.

Under the framework of this Protocol, Spanish NPPs will operate in long-term operation (LTO) until 2035. Units 1&2 of Almaraz NPP will operate until 2027 and 2028, respectively. Units 1&2 of Ascó NPP will operate until 2030 and 2032, respectively. Cofrentes NPP will operate until 2030, and Vandellós II NPP and Trillo NPP will operate until 2035.

As a consequence, the Spanish NPPs have submitted (or plan to submit) requests for operating licence renewal on the dates established in the current authorisations.

No significant progress was made in 2019 on the Salamanca mine project managed by Berkeley. The granting of the construction licence is still pending.

Sweden

At the end of June, units 1 & 2 at the Forsmark NPP in Sweden had reportedly received safety approvals to operate beyond their 40-year planned lifetimes, to 2028. The two reactors, which have a combined capacity of about 2 GWe, were awarded 10-year lifetime extensions by the Swedish Radiation Safety Authority (SSM). Plant owner/operator Vattenfall aims to keep the two units operational for a total of some 50 years since their startup in 1980 and 1981, respectively.

To maintain and secure technical expertise for its nuclear power plants, Swedish Uniper, Fortum and Vattenfall along with Finnish TVO decided to launch a joint trainee programme. Scheduled to start in 2020, the aim of the 15-month programme is to attract 15 university engineers or technicians to undergo training in Swedish and Finnish NPPs.

The Swedish former uranium mine Ranstad was released from regulatory oversight. The mine was used for uranium mining in 1965–1969, and was closed for profitability reasons. It was decommissioned and remediated by the Ranstad Industriecentrum AB.

Swedish support for nuclear energy has grown. According to recent polls by Novus published at the end of the year⁽⁵³⁾, 43% of respondents are open to new builds and 35% would like to continue exploiting the existing fleet until the end of its lifetime. Together, this amounts to 78% support for nuclear energy, up from 71% in 2017. The percentage of opponents fell to 11%, in contrast to the 20% seen in previous years.

United Kingdom

At the beginning of the year, Hitachi announced that it was putting on hold its plan to build two nuclear plants in the UK. Planning to cut jobs at its UK subsidiary Horizon Nuclear Power Ltd., the Japanese conglomerate is also considering a sale of Horizon Nuclear.

In May, the US DoE NNSA and the UK's Nuclear Decommissioning Authority (NDA) completed a multi-year effort to move excess HEU from the UK to the US for downblending into LEU, by removing nearly 700 kg of HEU.

In mid-2019, the Urenco Group officially opened their Tails Management Facility at the Capenhurst enrichment plant near Chester, used to deconvert depleted UF₆ to U₃O₈ and hydrogen fluoride vapour.

The UK Department for Business, Energy & Industrial Strategy announced in mid-2019 the imminent submission to Parliament of the revised UK draft National Policy Statement for geological disposal infrastructure. The siting process, which

53 <https://www.analys.se/wp-content/uploads/2019/11/20191122-analysgruppen-opinion-pressmeddelande.pdf>

started in England in December 2018 and in Wales in January 2019, is continuing.

In June, EDF announced the achievement of a major milestone at Hinkley Point C, with the completion of the foundations for the new station's first reactor. 9 000 m² of concrete was used, the biggest concrete pour in UK history at the time. EDF provided updates on the estimates of the Hinkley Point C project cost during the autumn. The cost is now estimated to be between GBP 21.5 billion and GBP 22.5 billion (up from GBP 19.6 billion).

In the same period, the UK's NDA announced that the final shipment of the used nuclear fuel had taken place from the Wylfa site in Wales. This was the last step of defueling all the UK Magnox sites, which consisted of 26 reactors, Wylfa being the biggest. The removed used fuel after the end of operation has been shipped to Sellafield for reprocessing – a total of 87 890 fuel elements.

Plutonium oxide samples from Sellafield were sent to Melox, where pellets were manufactured using the samples to examine compatibility with the MOX fuel specification. The aim is to assess if the entire existing separated plutonium stockpile stored at Sellafield is compatible with potential future MOX production.

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

Radioisotopes are used in medicine for the diagnosis and treatment of various diseases, including some life-threatening ones like cancer or cardiovascular and brain diseases. Over 10 000 hospitals worldwide use radioisotopes in about 100 different nuclear medicine procedures totalling almost 40 million medical exams each year. In the EU alone, more than 1 500 nuclear medicine centres deliver about 10 million procedures to patients each year. Nuclear medicine is an important tool for cancer management – about 60% of all nuclear medicine procedures are performed in oncology. The

therapeutic use of medical radioisotopes in cancer treatment is expanding, with a massive growth of the market for novel radiopharmaceuticals forecast for the next few years.

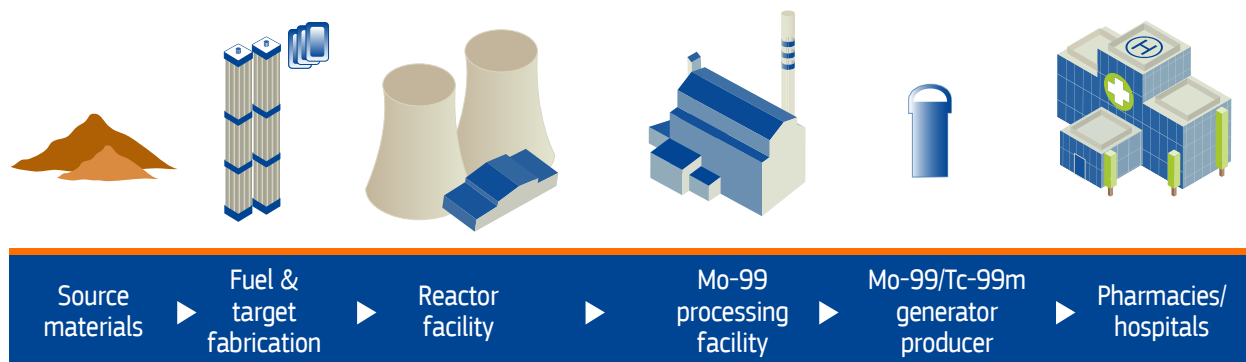
Currently, the main source of radioisotopes is nuclear research reactors, with several other non-fission technologies such as cyclotrons and accelerators in use or under development. Radioisotope production technologies mostly rely on highly specialised complex supply chains, which usually stretch across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

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

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

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

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



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

The NMEu Security of Supply Working Group⁽⁵⁴⁾ ensures effective coordination of reactor maintenance schedules to avoid and mitigate disruptions in the supply of Mo-99. The emergency response team (ERT) created within this Working Group and composed of representatives of research reactors, Mo-99 processors and Mo-99/Tc-99m generator manufacturers, monitors production and supply issues. This continuous monitoring makes it possible to identify potential shortages of Mo-99 and draw up mitigation action plans involving all stakeholders.

Following the 2018 outage of the NTP processing facility in South Africa, the ERT was activated for an extensive period and ensured supply with none to minimal level of disruption. In addition, the ERT addressed some supply disruptions at the ANSTO facility in Australia. The joint communication team, created with the European Observatory, provided regular information updates received from the ERT to various stakeholder groups, including the Council Working Party on Atomic Questions⁽⁵⁵⁾ and the Health Security Committee⁽⁵⁶⁾.

3.3.2. SAMIRA

In 2019, the European Commission's Directorate-General for Energy continued the preparatory work towards SAMIRA⁽⁵⁷⁾. SAMIRA seeks to identify opportunities and challenges for the use and development of ionising radiation and to discuss potential solutions to address challenges in areas where the EU can add value, alongside actions taken by other stakeholders. The supply of medical radioisotopes is one of the key areas identified for future action. A dedicated SAMIRA workshop was held in February 2019 to investigate the challenges and opportunities in this area.

Also in February, the European Commission published a study into the non-power applications of nuclear and radiation technology, including an evaluation of the demand and supply of medical radioisotopes⁽⁵⁸⁾. This contractor-led assessment examined a significant amount of evidence and supports the identification of issues and actions to take and address. These are largely concentrated in the medical field: secure the supply of radioisotopes for Europe, improve radiation protection and safety for European patients and medical staff and facilitate innovation in medical practice.

In June 2019, the Council adopted the Conclusions on Non-power Nuclear and Radiological Technologies and Application which welcomed the preparatory work undertaken by the European Commission towards the SAMIRA initiative and invited the Commission to develop an action plan highlighting areas that should be addressed as a priority containing specific actions to be undertaken in these areas. The Council Conclusions also invited the European Commission to support research on topics related to non-power applications of nuclear and radiological technologies, such as medical applications of ionising radiation, improved fuels for production of medical radioisotopes, optimised use of European research reactors and stressed the importance of delivering the research roadmap for medical applications in a timely manner.

3.3.3. Studies on the supply chain's back-end specificities

One of the key principles of the policy approach of the former OECD NEA High-Level Group on the Security of Supply of Medical Radioisotopes - HLG-MR (2009 – 2018)⁽⁵⁹⁾ was that all participants in the Mo-99/Tc-99 m supply chain should implement full-cost recovery. This would provide the economic incentives to develop Mo-99-related infrastructure and to fully finance operating costs. In this respect, in 2018–2019, the European Commission's JRC has been carrying out a research project (SMER-1), contributing to a sustainable and resilient supply of medical radioisotopes in the EU and, among other aspects, investigating the medical radioisotope reimbursement systems in the EU Member States. The final report, which explores good practices and differences in using Mo-99/Tc-99m and impact of health system reimbursement mechanisms, was finalised in 2019⁽⁶⁰⁾. Soon after the project finalisation, the JRC launched the complementary 12-month project (SMER-2), with the objective of providing the European Commission with current information on the radionuclide therapy market in the EU. The main purpose is to assist the assessment of the EU market in medical radioisotopes used for therapeutic purposes, in terms of emerging needs and security of supply, by providing data and expertise in areas of therapeutic applications, forecasting of demand, health technology assessment, challenges in research to clinical translation and financial requirements.

3.3.4. HEU to HALEU conversion of targets used for Mo-99 production

The importance of the conversion of targets used for Mo-99 production from HEU to LEU was highlighted in the Council Conclusions adopted in 2012, which called upon the European Commission to identify needs for research that might be supported by the Euratom research and training programme. As

54 <http://nuclearmedicineeurope.eu/security-of-supply/>

55 <http://www.consilium.europa.eu/en/council-eu/preparatory-bodies/working-party-atomic-questions/>

56 https://ec.europa.eu/health/preparedness_response/risk_management/hsc_fr

57 https://ec.europa.eu/energy/topics/nuclear-energy/radiation-protection/radiation-medical-use_en?redir=1

58 https://ec.europa.eu/energy/studies/european-study-medical-industrial-and-research-applications-nuclear-and-radiation-technology_en

59 <https://www.oecd-nea.org/med-radio/security/>

60 Study on sustainable and resilient supply of medical radioisotopes in the EU (JRC/BRU/2017/A.7/0001/OC)

a result, a research and innovation action grant (EUR 6.35 million) was awarded to the Heracles-CP⁽⁶¹⁾ project 'Towards the conversion of high performance research reactors in Europe', coordinated by the Technical University of Munich and involving five partners. The 5-year project, aiming to enter the new fuel type qualification phase, will be finalised in early 2020.

A complementary project, FOREVER⁽⁶²⁾, aimed at optimising the manufacturing process, kicked off in October 2017. The project, which will run until 2021, received an EU contribution of EUR 6.60 million. It is coordinated by the French Alternative Energies and Atomic Energy Commission (CEA) and involves nine research partners.

The Euratom 2019-2020 research work programme⁽⁶³⁾, adopted in December 2018, included a research call on optimised fuels for the production of medical radioisotopes, with an EU contribution of EUR 7.50 million. In 2019, the EU Qualify project was selected to answer this research call. Building on the data of the Heracles-CP and FOREVER projects, the EU Qualify project will generate data necessary for generic fuel qualification of two main fuel types uranium-molybdenum alloys (U-Mo) and 'High-loaded' U3Si2. The main objective of the project is to provide support for further investigation of future needs in terms of volume and fuel design requirements in line with relevant data for each EU research reactor type, and to prepare technical requirements for the safety of manufacturing, storage, transport and reprocessing of such research reactor fuel.

3.3.5. Projects related to the non-power applications of nuclear technology

In 2019, important projects in the area of non-power applications of nuclear technology were started or continued. The construction of the Jules Horowitz Reactor (JHR)⁽⁶⁴⁾ in France advanced. Spanish manufacturer Equipos Nucleares, S.A., S.M.E. (ENSA) has completed the manufacturing of three heat exchangers for the primary circuit, which were installed in early 2020.

The work on the Pallas⁽⁶⁵⁾ research reactor in the Netherlands continued. The municipality of Schagen agreed in April to the Pallas zoning plan. The revision of the plan makes the future location of Pallas in Petten possible.

Belgian Tractebel and Spanish Empresarios Agrupados signed the first contract (EUR 7.6 million) for the design of buildings and utilities for the Myrrha⁽⁶⁶⁾ research facility at the Belgian Nuclear Research Centre (SCK-CEN). MYRRHA – Multi-purpose hybrid Research Reactor for High-tech Applications is the world's first prototype of a subcritical lead-bismuth cooled reactor driven by a particle accelerator.

The SCK-CEN initiated project called NURA⁽⁶⁷⁾ aiming to develop next-generation radiopharmaceuticals. NURA will perform important research into radiopharmaceuticals for treating different types of cancer in cooperation with clinical and industrial partners.

SCK-CEN and the Institute for Radioelements (IRE) announced cooperation on the project Recumo⁽⁶⁸⁾ (Recovery of Uranium from Mo-99 production), to recycle highly radioactive residues resulting from IRE's production of radioisotopes for medical purposes.

IRE, in cooperation with the ASML company, also continued its work on the SMART⁽⁶⁹⁾ project – the accelerator based production of Mo-99.

The Advancing Nuclear Medicine consortium, led by NRG, received a EUR 6.8 million subsidy to develop FIELD-LAB⁽⁷⁰⁾ aimed at accelerating the development and introduction of new radiopharmaceuticals.

SHINE Medical Technologies⁽⁷¹⁾, a US-based company, announced its intention to site, construct and operate a medical radioisotope production facility in Europe, similar to that currently being constructed in Janesville, Wisconsin. SHINE plans to use a low-energy, accelerator-based neutron source to fission an LEU target dissolved in an aqueous solution to produce Mo-99. SHINE expects to begin production of Mo-99 in the US in 2021, with commercial production starting in 2022.

61 <https://cordis.europa.eu/project/id/661935/fr>
 62 https://cordis.europa.eu/project/rcn/210823_en.html
 63 http://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/euratom/h2020-wp1920-euratom_en.pdf
 64 <http://www-rjh.cea.fr/index.html>

65 <https://www.pallasreactor.com/en/>
 66 <https://myrrha.be/>
 67 <https://www.sckcen.be/en/projects/hura>
 68 <https://www.sckcen.be/en/projects/recumo>
 69 <https://www.ire.eu/media-room/news/ire-well-positioned-to-develop-waste-free-non-fission-medical-isotopes>
 70 <https://www.nrg.eu/about-nrg/news-press/detail/news/petten-investeert-in-nieuwe-nucleaire-geneesmiddelen-nederland-krijgt-voortrekkersrol-in-de-ontwik.html?L=1&cHash=a7cbd5e7b3984652055c99c86c7b976d>
 71 <https://shinemed.com/>

4. World market for nuclear fuels

According to the IAEA, there were 450 nuclear power plants in operation on 31 December 2019. Around 10% of the world's electricity was generated from 398.9 GWe installed net capacity in 30 countries. World nuclear power generation increased by 2.5 GWe compared to 2018, with the new generation capacity coming mostly from Asia. The year saw four new plant connections to the grid, construction launch for three more and the permanent shutdown of five plants. Expansion, as well as short to long-term growth prospects, remains centred in Asia, home to 34 of the 53 reactor sites under construction at the end of 2019.

The nuclear sector welcomed the EU's plans to become the world's first climate-neutral continent by 2050, including a sustainable financial initiative to support this as announced by the President of the European Commission on 11 December 2019. Foratom ⁽⁷²⁾ noted the Intergovernmental Panel on Climate Change and the International Energy Agency (IEA) estimates according to which decarbonisation goals cannot be achieved without nuclear energy.

According to recent data from IEA, higher nuclear power generation in advanced economies has avoided over 50 million tonnes of CO₂ worldwide. The IEA's World Energy Outlook 2019 forecasts that low-carbon sources will provide over half of total electricity generation by 2040. In its Sustainable Development Scenario (SDS), the IEA projects that additional capacity for nuclear generation will grow at a rate of about 15 GWe per year, bringing the nuclear contribution to decarbonised electricity production to 3 435 TWh in 2030 and 4 409 TWh in 2040 – about 11% of the world's generation.

Nonetheless, the 2020 SDS assumption of 438 GWe of installed nuclear power capacity will not be met, putting the 2025 target of 490 GWe into question. The nuclear phase-out policies in South Korea, Germany, Belgium, and Taiwan are expected to lead to the closure of about 6% of the current capacity. According to IEA projections ⁽⁷³⁾, unless spending on nuclear generation doubles compared to recent years, CO₂ emissions risk growing from 33 243 million tonnes in 2018



Uranium mineralisation at Alligator River Project © Virmy Resources

to 34 860 million tonnes in 2030 and 35 589 million tonnes in 2040. Supranational finance institutions and funds are expected play a key role in supporting the SDS ⁽⁷⁴⁾. New developments, such as the use of Accident Tolerant Fuel (ATF), could potentially help to achieve the SDS targets. The year of 2019 saw advances in this respect in China, India, Japan, Russia, the US and Europe.

China

At the end of 2019, China had 48 nuclear power units in operation and 10 under construction, expected to become 12 in 2020. In June 2019, unit 6 of the Yangjiang site, a Chinese design, ACPR-1000, was connected to the grid. The same month, unit 2 of the Taishan site was connected to the grid, becoming the second European EPR-design reactor to achieve this milestone. The year recorded a 5% rise in electricity generation, and the share produced by nuclear power plants went up by 18%. Chinese demand for uranium is estimated to reach 10 800 tonnes in 2020, rising to 16 300-18 500 tonnes by 2025. Media reports that 72 universities in China are running programmes on nuclear engineering, enrolling some 3 000 undergraduates in nuclear engineering each year.

72 <https://www.foratom.org/press-release/foratom-welcomes-parliaments-cop-25-resolution/>

73 <https://www.world-nuclear-news.org/Articles/IEA-highlights-deep-disparities-in-global-energy-s>

74 <https://www.spglobal.com/ratings/en/research/pdf-articles/supranationals-special-edition-october-2019>

India

India's energy consumption is projected to rise by 15% to 2024 compared to 2017. India had previously announced plans to build 63 GWe of nuclear capacity by 2032. In January 2019, the government of India announced that nuclear capacity targets for 2032 were being revised down from the earlier announced 63 GWe. Kudankulam 3 and 4, which are being built with Russian input, are expected to be the first foreign units to become operational. Negotiations with France and the US were also being pursued. According to 2019 plans, India intends to complete the Kakrapar-3 and 4 units and the RAPS-7 and 8 units in 2022. Ongoing construction of Kudankulam units is due for completion in 2025. The Russian-designed VVER-1200 units will supply up to 2 400 MWe to both the Indian and Bangladeshi power networks. Reportedly, India re-processed 400 tonnes of spent fuel in 2019, with plans to grow capacity and reach 1 000 tonnes by 2021.

Japan

According to data in late 2019, four Japanese power plants in outage since the Fukushima incident were expected to restart in 2020, following a protracted regulatory recertification process. For nine others that also received a go-ahead, restart in 2020 is not certain. In June 2019, it was reported that Chugoku Electric Power Co had deferred construction works at their Kaminoseki site to January 2023, meaning that three units were under construction at the end of 2019 in Japan (Ohma, Higashidori-1, Shimane-3). In April 2019, the permanent shutdown of Kyushu EPC's Genkai-2 unit was announced. Also in April, Japanese media reported on the planned delivery in 2020 to Kansai Electric Power Company of MOX fuel assemblies fabricated in France for the Takahama 3 and 4 nuclear power plants. Hitachi announced in January 2019 its withdrawal from new build plans in the UK.

Russia

In May 2019, Rosatom was reported to hold a USD 137 billion order book to build two dozen nuclear reactors worldwide⁽⁷⁵⁾. Besides nine reactors under construction in Turkey, Belarus, India, Bangladesh and China, 19 more projects are planned according to Rosatom and additional 14 proposed, almost all in emerging markets around the world. Rosatom has signed intergovernmental cooperation agreements with authorities in Saudi Arabia, UAE, Jordan, Algeria, Tunisia, Sudan and Morocco.

In December 2019, the nuclear barge Akademik Lomonosov – a pilot project and a 'working prototype' for a future fleet of floating nuclear power plants and on-shore installations based on Russian-made SMR – began delivering power.



View of Urenco enrichment hall © Urenco

Rosatom announced⁽⁷⁶⁾ plans to introduce TVEL-manufactured accident-tolerant fuel (ATF) at one of the VVER-1000 units of Rostov NPP.

USA

In the beginning of the year, the US Energy Information Administration (EIA) provided long-term energy projections in its Annual Energy Outlook 2019⁽⁷⁷⁾. The document considers how the US and world energy markets will operate until 2050.

In the USA, uranium (U_3O_8) production is estimated to have fallen to a historical minimum at 69 t U_3O_8 in 2019, 18 times lower than in 2015, according to Energy Information Administration (EIA) data⁽⁷⁸⁾.

In 2019, uranium producers and suppliers of enrichment services in the US expressed their concerns to the US Department of Commerce about the impending expiry (at the end of 2020) of the 'Suspension Agreement' (i.e. quotas) with Russia. In July the US President rejected a petition from uranium miners and asked for a fuller analysis of national security considerations.

The Federal Strategy to Ensure Secure and Reliable Supplies of Critical Materials⁽⁷⁹⁾ released by the US Department of Commerce in June, provides an action plan to ensure the US maintain a reliable supply of 35 identified "critical minerals," including uranium.

In July 2019, the world's first complete set of lead ATF test assemblies was loaded into the US Vogtle-2 reactor. The assemblies were designed by Framatome.

75 <https://www.intellinews.com/russia-s-nuclear-power-exports-are-booming-160796/>

76 <https://world-nuclear-news.org/Articles/Rosatom-plans-accident-tolerant-fuel-loading>

77 <https://www.eia.gov/outlooks/aeo/pdf/aeo2019.pdf>

78 https://www.eia.gov/uranium/production/quarterly/archive/3rdqtr_dupr_2019.pdf (differences in least significant digit are possible due to conversion factors).

79 <https://www.commerce.gov/news/reports/2019/06/federal-strategy-ensure-secure-and-reliable-supplies-critical-minerals>

Following the DoE decision to invest in the production of HALEU, a three-year contract was signed with Centrus Energy Corp. in November, to deploy a cascade of centrifuges to demonstrate production of HALEU fuel for advanced reactors.

IAEA

December 2019 saw the arrival of the second and final shipment of LEU at the IAEA's LEU Bank hosted by Kazakhstan. The internationalisation of nuclear supply assurances has been on the agenda of the UN since 1946, and the IAEA is authorised by its statute to play a role in this respect. The IAEA and ESA are the only two multinational bodies with statutory legal provisions related to property and stock-building for special fissile materials.

4.1. Primary uranium supply

Following a period of contraction since 2016 (a fall of 5% in 2017 and 10% in 2018), uranium concentrate production levels show signs of stabilisation. Primary uranium production has declined in the past 3 years primarily due to oversupply, demand contraction and economic decisions from the principal Kazakh and Canadian operators.

The total production for 2019 remains stable compared to 2018, at 53 656 tU (53 498 tU in 2018). A timid recovery is therefore expected in 2020. Production from Kazakhstan is on

the rise, with a 42.5% share this year (40.06% share in 2018). Despite a slight contraction in output, Canada retains second place with a 12.9% share of production. Australian output saw a small increase, keeping third place and a 12.3% share of the market.

While the ranking of the top three world producers remains unchanged, a significant drop in production levels is observed in the US and in Ukraine. No evidence of recovery could be seen in Niger production, and Namibian producers reportedly continue to experience difficulties in ramping up to maximum capacity. A significant share of the produced concentrates remains contracted out in long-term arrangements, and not available for trading.

The sharp fall in uranium concentrate production in the US, now at levels tenfold lower compared to 2015, was the object of a petition to the US President in 2019 (see above). The petition was dismissed, but an expert group on the matter has been set up.

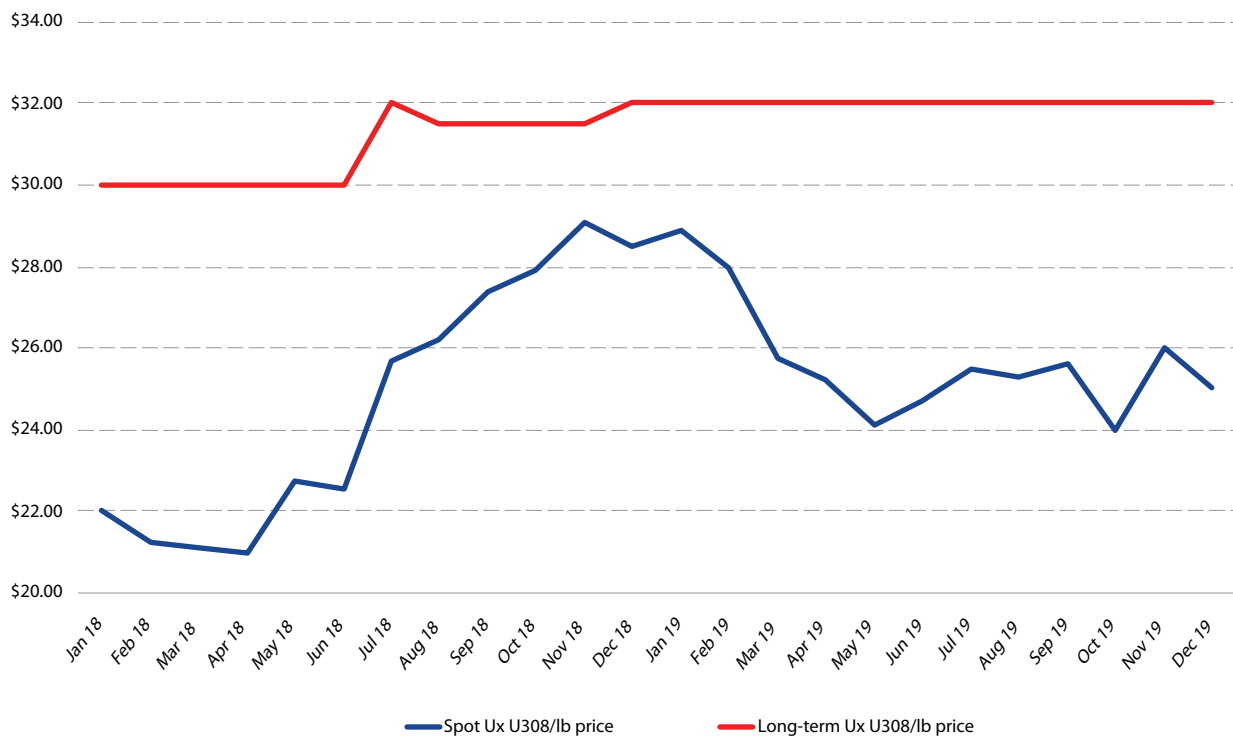
Following a decline in the first two quarters of 2019, the uranium spot price recovered slightly in the second half of 2019 to end at USD 24.9 per pound (28.50 at end 2018). The long-term estimate remained stable at USD 32 per pound throughout 2019.

Some market players anticipate a bullish period, with prices possibly reaching USD 50 per pound by 2021.

Table 8. Natural uranium production in 2019 (compared to 2018, in tonnes of uranium equivalent).

Region/country	Production 2019 (final)	Share in 2019 (%)	Production 2018 (final)	Share in 2018 (%)	Change 2019/2018 (%)
Kazakhstan	22 808	42.5%	21 705	40.6%	5%
Canada	6 938	12.9%	7 001	13.1%	-1%
Australia	6 613	12.3%	6 517	12.2%	1%
Namibia	5 476	10.2%	5 525	10.3%	-1%
Niger	2 983	5.6%	2 911	5.4%	2%
Russia	2 911	5.4%	2 904	5.4%	0%
Uzbekistan	2 404	4.5%	2 404	4.5%	0%
China	1 885	3.5%	1 885	3.5%	0%
Ukraine	801	1.5%	1 180	2.2%	-32%
Others	424	0.8%	538	1.0%	-21%
South Africa	346	0.6%	346	0.6%	0%
United States	67	0.1%	582	1.1%	-88%
Total	53 656	100.0%	53 498	100.0%	0%

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

Figure 12. Monthly spot and term U₃O₈/lb prices (in USD)

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

World market demand for enriched uranium products remains estimated at 7 879 tU, considering substitution from secondary sources. Market dynamics in the primary and secondary supply market are inextricably linked and significant changes are therefore expected to start in 2020.

4.2. Secondary sources

In 2019, world uranium production continued to provide the bulk of world reactor requirements, complemented by secondary supply sources, which included government-held or commercial inventories of natural, enriched uranium, fabricated fresh fuel assemblies, downblended uranium, reprocessed uranium and plutonium recovered from spent fuel, depleted uranium, and uranium saved through underfeeding.

With potential for significant impact on the market, plans for the re-enrichment of a part of the US DoE's depleted uranium stocks have been announced, and an agreement to that end was concluded with a GE-Hitachi venture GLC on laser enrichment (see Section 4.5.). US DoE sources indicate an expected total of 6 000 tU from the deal ⁽⁸⁰⁾, but not before 2024.

Mirroring the 'stripping' practices of the 1980s, the post-Fukushima period has seen excess SWU capacity being used to underfeed enrichment plants and/or re-enrich depleted tails

to natural uranium, leading to higher uranium inventories also at the enricher's stores. Russian underfeeding is estimated at more than 4 500 tU/year. Since the end of the US-Russia agreement on HEU downblending, the importance of secondary supplies has dwindled, but still remains significant, estimated at about 18-25% of the total.

Several States, including US and Russia, also hold HEU stockpiles, part of which is available for downblending. Such inventories are relevant for HALEU (19.75% assay) products, particularly for research reactors and ongoing development projects.

Recycling of spent fuel for the production of uranium oxides or mixed uranium-plutonium oxides may also be considered a secondary source of supply. The inventory of separated, recyclable materials worldwide is estimated by the WNA in the range 110-195 ktU, depending on whether uranium and plutonium from non-civilian stocks is also included.

According to specialised press reports, the Russian government holds an estimated 141 538 tU, even though most of the material must undergo processing before being used. Besides reprocessed uranium, Russia reportedly has downblended uranium left from the end of Russia-US agreement concerning the disposition of highly enriched uranium extracted

80 <https://www.energy.gov/sites/prod/files/2017/03/f34/ERI%20Analysis%20Jan%2012%202017.pdf>, table 3.6.

from nuclear weapons ⁽⁸¹⁾. Such uranium could more easily enter the market. Another significant part of the inventory is in the form of depleted uranium. Tails for re-enrichment have low assays, but given Russia's reportedly large excess enrichment capacity, the volume of re-enriched tails could remain high in the period 2020-2028.

IAEA experts generally consider that, on average, commercial inventories are driven by utilities (about 2 years of forward requirements), fuel producers (about 0.5 years of forward requirements), and around 10% of annual requirements for brokers, traders and other investors. Due to the slow-down post-Fukushima, utility inventories of uranium concentrates remain significant. US utilities are estimated to hold in excess of 43 080 tU. Post-Fukushima, Japanese utilities are reported to hold over 23 078 tU, the equivalent of 4-5 years fleet average operation.

To summarise, in 2020 and beyond, the inventory of secondary sources of supply could be expected to continue offsetting primary uranium production and depressing the price of concentrates, unless a significant change occurs in demand.

Towards 2028 and beyond, the situation might ease if anticipated reductions in secondary supplies such as the re-enrichment of depleted uranium materialise. On this account, various analysts have underlined the need for substantial investment in uranium mining, prospecting and development throughout the decade.

4.3. Uranium exploration

Global expenditure in uranium mineral exploration and development has decreased in recent years. The future development in uranium exploration will depend on multiple factors, such as energy demand in a mid-term perspective, share of nuclear in the energy mix, actual uranium production, or results of efforts to develop safe mining practices and new exploration technologies with less environmental impact. It will be also affected by the wider trends as it is expected that new energy technologies and expansion of renewable energies could prompt a new growth in energy minerals exploration expenditure in the coming decade.

In the near future, the list of mining sites closing down or being placed in care and maintenance (C&M) should continue to grow. In October 2019 the decision was taken to close down the Akouta (Niger) mining site by end March 2021, adding to list of mines placed in C&M in recent years, which includes Rabbit Lake and McArthur River (Canada), and Langer Heinrich (Namibia). Pre-feasibility studies on the reopening of such sites suggest it will be uneconomical to do so unless uranium prices rise significantly above 2019 levels.

In spite of depressed prices, some uranium exploration and development is ongoing, both in less explored regions and in mature sites such as Canada. For example, in December 2019 Orano Mining established a joint venture, Nurlikum Mining LLC, to develop uranium mining projects in Uzbekistan. Some projects on the horizon, such as the Arrow deposit in Canada, could significantly alter the global uranium market cost structure in the medium term.

4.4. Conversion

Commercial conversion plants are located in the USA, Canada, France, Russia and China. The world's primary conversion capacity in 2019 is estimated at 62 000 tU, of which only 34 500 tU is currently used ⁽⁸²⁾.

In the EU, the new capacity is provided by Orano's Comurhex, operating between two sites in France. At the French Malvesi site, a new unit for the production of 300 tU/y of high purity UO₂ from UNH began ⁽⁸³⁾ construction in 2019, and is due for operation in 2022.

China's capacity is expected to grow considerably through to 2025 and beyond to keep pace with domestic requirements. A 9 000 tU/y plant is said to be under construction at Lanzhou, and another 3 000 tU/y plant is reportedly under construction at Hengyang ⁽⁸⁴⁾.

It is expected that in the short-medium term, the global nuclear fuel market will continue to be served by current five primary converters: Orano, CNNC, Rosatom, Cameco and ConVerDyn. World requirements are estimated to rise to approximately 65 000 tU by 2020 and 72 000 tU by 2025.

81 Hearing Before the Committee on Governmental Affairs, United States Senate, One Hundred Third Congress, First Session, March 9, 1993

82 <https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/conversion-enrichment-and-fabrication/conversion-and-deconversion.aspx>

83 https://www.orano.group/docs/default-source/orano-doc/groupe/publications-reference/rapport_tsn_malvesi_2018.pdf, p. 13

84 <https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/conversion-enrichment-and-fabrication/conversion-and-deconversion.aspx>

Table 9. Commercial UF₆ conversion facilities

Company	Nameplate capacity in 2019 (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

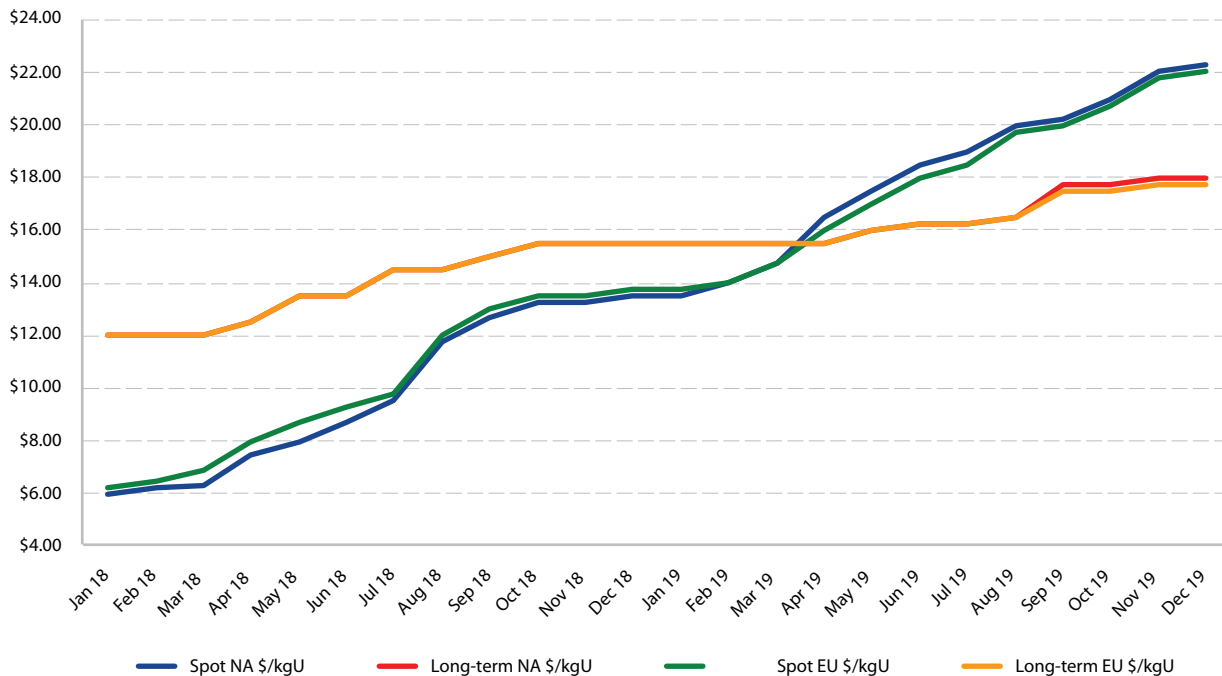
*** Activity suspended since end of 2017

Supply in the conversion market continues to tighten after the halting of the ConverDyn plant at the end of 2017 and the shift from Comurhex I to the new plant Philippe Coste.

Price recovery in 2019 was accentuated by some outsourcing of conversion services. The spot price rose from USD 13.75/

kgU at the end of 2018 to USD 22.00 at the end of 2019 (the European conversion price published by UxC), while the long-term price rose from USD 15.50/kgU at the end of 2018 to USD 18.00 at the end of 2019.

Figure 13. Uranium conversion price trends (in USD)



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4.5. Enrichment

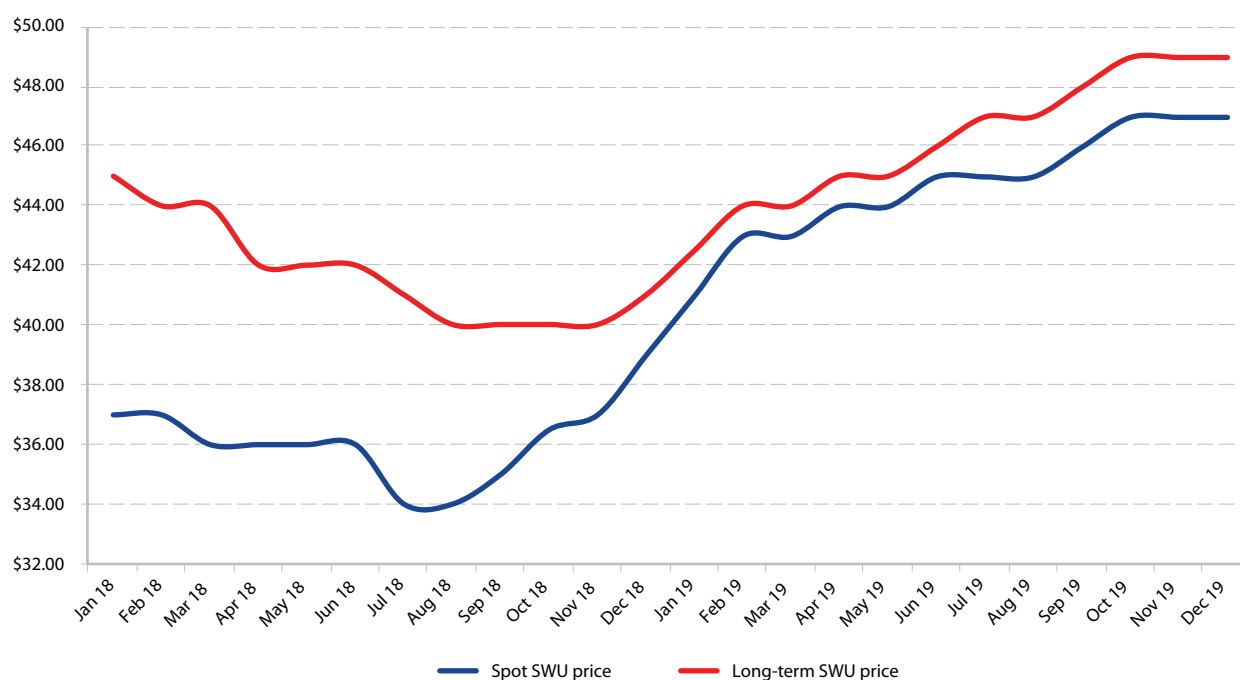
Australia's Silex Systems and Canada's Cameco agreed to buy out GE-Hitachi Nuclear Energy's ownership share of GE-Hitachi Global Laser Enrichment (GLE), a company trying to commercialise Silex's technologies to produce enriched uranium. Cameco would increase its stake in GLE to 49%, Silex would have 51%. The agreement's signature is conditional to the US DoE's approval to continue a 2016 agreement under which GLE was authorised to purchase DoE-owned depleted uranium that would be used in a laser enrichment facility to be built at the Kentucky enrichment facility.

Urenco USA announced a new programme covering the production of HALEU at a dedicated unit to be built at its US uranium enrichment facility.

The US DoE awarded a contract to Centrus Energy to demonstrate HALEU production to support research and development programmes, including development of advanced reactor fuels. The contract includes licensing, constructing, assembling and operating of AC100M centrifuges in a cascade formation to produce HALEU at the American Centrifuge Plant in Ohio.

Russian Electrochemical Plant JSC announced that works were completed on its new generation 9+ gas centrifuges. It is a part of the modernisation of the facility which also received a 30-year life extension, now licensed to operate until 2048.

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.

Table 10. Operating commercial uranium enrichment facilities, with approximate 2019 capacity

Company	Nameplate capacity (tSW)	Share of global capacity (%)
Rosatom (Russia)	27 933	46%
Urenco (UK/Germany/Netherlands/United States)	18 414	30%
Orano (France)	7 500	12%
CNNC (China)	6 750	11%
Others * (INB, JNFL)	55	0%
Total nameplate capacity	60 652	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

4.6. Fuel fabrication

All over the world, fuel manufacturers reported intensified efforts towards producing Accident Tolerant Fuel (ATF), with increased financial support from governments.

Framatome announced that the US DoE had granted it USD 49 million in funding over a 28-month period to speed up development of its Enhanced Accident Tolerant Fuel (EATF). EATF features were combined with its GAIA fuel assemblies, nuclear industry's first full-length EATF, which had been delivered and loaded into Unit 2 at Georgia Power's Vogtle plant during the spring refuelling outage. Framatome fabricated the fuel assemblies at its fuel manufacturing facility in Richland, Washington, as part of a 2017 contract with Southern Nuclear.

China General Nuclear reported that it had begun irradiation testing of a prototype ATF in a research reactor. TVEL announced that the first batch of experimental ATF assemblies was loaded into the MIR research reactor for testing at the State Research Institute of Nuclear Physics in Dimitrovgrad, Russia, with a view to bringing to the market a Russian ATF design.

TVEL also supplied a fuel batch for the Chinese 20MW experimental fast reactor (CEFR). The fuel assemblies shipped to the CEFR were manufactured in Elektrostal in Russia and were supplied under a broader supply contract between TVEL, China Nuclear Energy Industry Corp. and the China Institute of Atomic Energy in Beijing.

TVEL signed a contract with the Czech power company ČEZ for development and supply of new VVER-440 fuel design RK 3+. This fuel is specifically designed for Czech Dukovany NPP, is to be tested, and must be licensed by the Czech State Office for Nuclear Safety.

In order to create the conditions for diversification and to ensure a competitive environment for VVER-1000 fuel supplies, six lead test assemblies designed and manufactured by Westinghouse Electric were licensed and loaded in 2019 into Czech Temelin NPP Unit 1.

Westinghouse announced it had been awarded USD 93.6 million in funding from the US DoE to support the development of its EnCore ATF design. EnCore Fuel programme includes the development in two phases of both short- and long-term products. In September EnCore ATF was for the first time loaded into a reactor core. Two test assemblies were placed into Exelon's Byron NPP Unit 2.

Westinghouse also submitted revised Environmental Report for a 40-year licence renewal of its Columbia Fuel Fabrication Facility to the US Nuclear Regulatory Commission (NRC).

Energatom and Westinghouse signed a preliminary agreement for Westinghouse to produce fuel for Ukraine's VVER-440 reactors, operated by Energatom. The agreement enables Ukraine to reduce its dependence on Russian fuel supplier

TVEL and to work together with Westinghouse to develop and implement advanced VVER fuel technologies.

The US DoE reported that the proposed use of roughly 10 tonnes of its HALEU, produced and stored at Idaho National Laboratory (INL) to fabricate fuel, would not have a significant impact on the environment. This allows for fabrication of HALEU fuel at INL 'supporting near-term research, development and demonstration needs of private-sector developer and government agencies, including advanced reactor developers', according to the DoE. Production of HALEU fuel at INL will require an expansion of the fuel fabrication capability, including the purchase of new equipment.

The Chinese CNNC company announced that its subsidiary Nuclear North Nuclear Fuel has delivered the first batch of China-fabricated fuel assemblies to the world's first AP1000 reactor Sanmen 1. CNNC informed also its intentions to fabricate fuel assemblies for CAP-1400 reactors.

4.7. Reprocessing and recycling

It is up to the individual Member States and their corresponding national policies whether they opt to consider the spent nuclear fuel as radioactive waste or as a valuable source of new material through reprocessing. According to the European Commission report⁽⁸⁵⁾ dated 17 December 2019, 7 Member States of 28 had reprocessed spent fuel or chosen the reprocessing option, and 2 Member States are keeping that possibility open.

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

The generation of spent fuel worldwide amounts to around 10 000 – 13 000 tHM/y. Respectively the global reprocessing capacity is about 2 000 tHM per year and is carried out by Orano in La Hague, France with a capacity of 1 700 tHM/y and Chelyabinsk, Russia with a capacity of 400 tHM/y. By the end of 2018/start of 2019, the total amount of spent fuel removed from reactor cores worldwide amounted to around 400 000 tHM, of which the third has been reprocessed and the rest stored.

85 Report from the European Commission to the Council and the European Parliament on progress of implementation of Council Directive 2011/70/Euratom and an inventory of radioactive waste and spent fuel present in the Community's territory and the future prospects. <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52019DC0632&from=EN>

Reprocessed uranium is used in mixed oxide (MOX) fuel, which consists of recovered uranium and plutonium. In Europe MOX fuel is produced in Melox-plant in Marcoule, with an authorised production capacity of 195 tHM/y. The EU Member States in possession of nuclear power plants in 2019 using MOX fuel were France, the Netherlands, Belgium, Germany and the UK.

In the UK the stockpile of recovered plutonium is stored at the Sellafield site in the north of England. In November 2019,

a sample of this material was sent to Orano's Melox facility in order to determine the usability of the material in MOX fuels. This will facilitate decision-making when choosing an option for recycling the material at the Sellafield site, as to date there is no clear option for final disposal in the UK. Outside the EU, MOX fuel is produced in Zheleznogorsk, Russia. Japan is currently also building a plant for producing MOX fuel but it will not be operational until around 2022.

5. ESA management, administration and finances

Legal status

The Supply Agency, established directly by Article 52 of the Euratom Treaty, has been operating since 1 June 1960.

It is endowed with legal personality and financial autonomy ⁽⁸⁶⁾ and operates under the supervision of the European Commission on a non-profit-making basis.

Seat

ESA's seat has been in Luxembourg since 2004, which was confirmed by the 2008 ESA statutes. Together with the European Commission, ESA has concluded a seat agreement with the government of the Grand Duchy of Luxembourg.

Financing

Since 1960, ESA has relied on a contribution from the EU general budget.

- ESA's present financial situation results from the 1960 Council decision to postpone indefinitely the introduction of a charge on transactions (contracts for the purchase of nuclear materials by EU utilities), which had been intended to cover ESA's operating costs.

- The European Commission directly covers some of ESA's administrative needs, adopts its budget and transfers the contribution.

Financial Regulation

For its financial operations, the Euratom Supply Agency applies the relevant provisions of its statutes as well as the EU Financial Regulation ⁽⁸⁷⁾ and the accounting rules and methods established by the European Commission. Article 68 of the EU Financial Regulation stipulates its applicability to the implementation of the budget for ESA.

Since 2018, ESA is exempt from the external charge-back of any services provided to it by the European Commission ⁽⁸⁸⁾. The exemption continued to have a positive impact on ESA's administrative capacity.

Financial accounts

In 2019, the assets owned by ESA totalled EUR 740 564. They were financed by liabilities of EUR 7 486 (1%) and equity of EUR 733 078 (99%). The Supply Agency has a capital of EUR 5 856 000. An instalment of 10% of the capital is paid at the time of a Member State's accession to the EU. On 31 December 2019, the amount of the instalments called up and reflected in ESA's accounts stood at EUR 585 600.



86 Article 54 of the Euratom Treaty

87 Regulation (EU, Euratom) 2018/1046 on the financial rules applicable to the general budget of the Union

88 Commission Decision C(2018) 5120, Annex 21

Budget



Budget implementation

The Supply Agency's budget in 2019 amounted to EUR 223 000 (EUR 123 000 in 2018), increased by 81% for an IT project to develop a new state-of-the-art application for management of nu-

clear contracts (NOEMI). Its revenue and expenditure were in balance. The entire budget of EUR 223 000 was financed by a contribution from the EU budget.

On 31 December 2019, ESA's accounts show a budget execution of EUR 222 689, or 100% of commitment appropriations (against 98% in 2018). The budget and final annual accounts are published on ESA's website (<http://ec.europa.eu/euratom>).

Figure 15. Budget execution by expenditure type

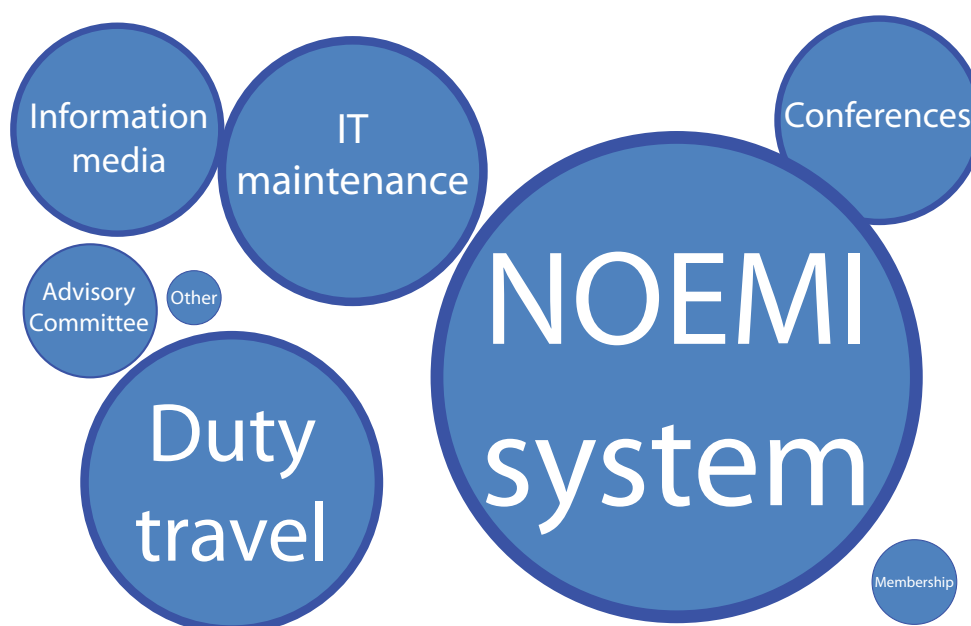


Table 11. Budget execution by expenditure type

BUDGET	EUR 222 689
IT system development (NOEMI system)	EUR 104 337
Duty travel	EUR 37 600
IT maintenance	EUR 32 861
Purchase of Information media	EUR 18 279
Advisory Committee & Working Groups	EUR 17 452
Conferences (participation & organisation)	EUR 7 783
Membership in nuclear organisations	EUR 2 980
Other (bank & representation charges)	EUR 1 397

Table 12. Overview of expenditure financed directly by the European Commission

STAFF	Salaries & allowances
	Socio-medical infrastructure
	Training
INFRASTRUCTURE & OPERATING EXPENDITURE	Rental of buildings and associated costs
	- Buildings, infrastructure and associated costs
	Information and communication technology
	- EC software applications
	Movable property and associated costs
	Current administrative expenditure
	- Stationary and office supplies
	Postage / Telecommunications
	- Computer hardware (servers, PCs and equipment)
	- Telecommunications
	Information and publishing
	- Publications – Official journal

The bulk of ESA's administrative expenses, including salaries⁽⁸⁹⁾, premises, infrastructure, training and some IT equipment, is covered directly by the European Commission budget, and is not acknowledged in ESA's accounts. According to an internal estimate⁽⁹⁰⁾, ESA's total cost covered by the Commission in 2019 amounted to EUR 2 550 000.

This off-budget expenditure and the underlying transactions are included in the EU annual accounts and are considered as non-exchange transactions for ESA. Thus, ESA's operating costs are partly covered by its own budget; this includes duty travel, the IT system and its stand-alone computer centre, and media subscriptions.

Audit by the European Court of Auditors

The European Court of Auditors (ECA) performs an audit of ESA's financial and budgetary accounts and the underlying transactions on an annual basis in line with internationally accepted public-sector auditing standards. The ECA's responsibility is to provide the European Parliament and the Council with a statement of assurance as to the reliability of the annual accounts and the legality and regularity of the underlying transactions. ESA duly notes ECA's observations and takes the necessary measures as needed. It also follows carefully the observations of cross-cutting nature accompanying the Annual Report of the EU agencies⁽⁹¹⁾.

In 2019, the ECA signed off the 2018 accounts and issued a clean opinion, as they present fairly the financial situation, operations and cash flows in line with the accounting rules. In addition, the ECA provided a clean opinion on the legality and regularity of ESA's revenue and payment operations. Building on the audit outcome, ESA further reinforced the monitoring of its budget execution in 2019.

Discharge

The European Parliament, acting on a Council recommendation, is the discharge authority for ESA. On 26 March 2019, the European Parliament granted ESA's Director-General discharge for the implementation of the budget for the 2017 financial year⁽⁹²⁾.

Staff allocation

ESA staff are European Commission officials and ESA's establishment plan is incorporated into the global staff numbers of the European Commission. For 2019, the number of authorised posts was reduced to 17 (25 in the 2018 budget). At the end of the year, ESA held 17 permanent posts, which translated into 16.5 full-time equivalents. The Supply Agency had an acting Director-General between January and March 2019. Following appointment by the Commission, the new Director-General has been in charge since April 2019.

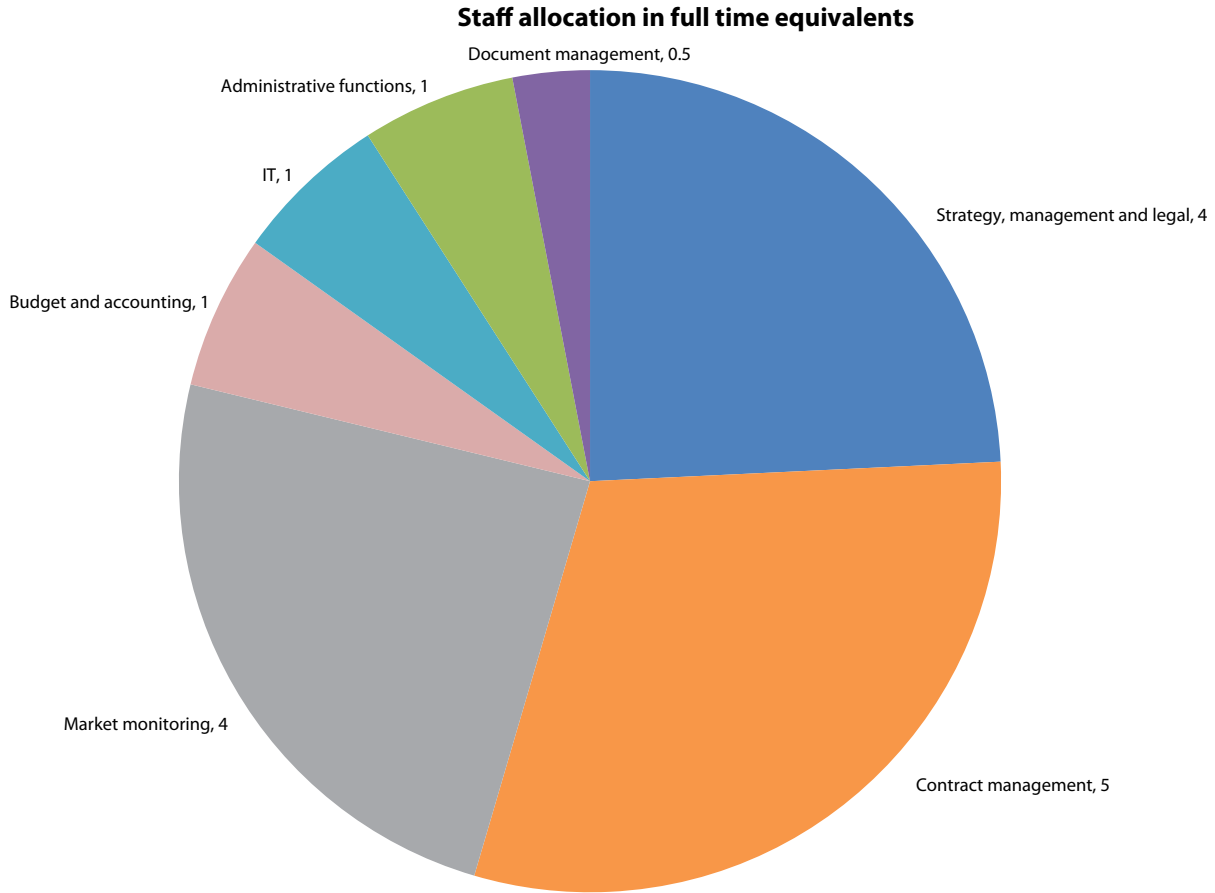
89 Salaries are paid by the European Commission in line with Article 4 of ESA's Statutes and are not charged to the Agency's budget.

90 Based on European Commission methodology

91 https://www.eca.europa.eu/Lists/ECADocuments/auditinbrief_agencies_2018/auditinbrief_agencies_2018_en.pdf

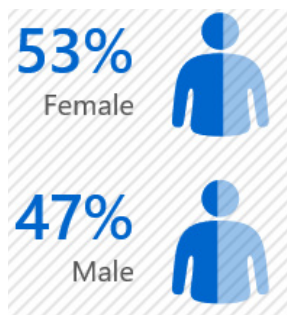
92 European Parliament decision of 26/3/2019 (P8_TA-PROV (2019)0280, 2018/2199(DEC))

Figure 16. Full-time equivalent allocation per activity



Equal Opportunities

We provide equal career opportunities for our staff at all levels. ESA employs equal proportions of women and men in its workforce. Women make up 53% of ESA staff and men 47%. The equal opportunities policy is also reflected in management positions, which are also equally distributed.



Information system innovation in NOEMI



IT reinforced: Launch of NOEMI project

An ambitious technological milestone was initiated in 2019 with the endorsement of the IT project NOEMI by the European Commission’s Information Technology and Cybersecurity Board. NOEMI stands for ‘Nuclear Observatory and ESA Management of Information’. It consists of designing a new technological platform that will securely host sensitive nuclear contracts’ data and will reinforce our monitoring capabilities of the nuclear materials and fuel market.



Communication and visibility

In 2019, ESA focused on more streamlined outreach to stakeholders in industry, research and national administrations. The number of visits to the website is stable, and in 2020 the website will undergo a complete restructure and operate from a more efficient platform. ESA further increased its media profile by creating Twitter and LinkedIn accounts. Engagement rates on both platforms are increasing, and profile visits are particularly strong when ESA tweets real-time information on publication of reports or press releases relating to core activities. The multiplier effects of these platforms are fast becoming an important aspect of ESA's communication actions.

Internal control and risk management

ESA has developed and implemented a series of internal measures to provide assurance that:

- its operational and administrative activities are effective and efficient;
- all legal and regulatory requirements are met;
- financial and management reporting is reliable; and
- assets and information are safeguarded.

In 2019 the Supply Agency applied the Commission's Internal Control Standards for effective management as adopted by the Communication SEC(2007)1341 and updated in June 2014. The standards supplement the EU Financial Regulation and other applicable rules and regulations. ESA performed risk assessment with particular focus on finance and IT. ESA also started to develop the new internal control framework that will be effective from 2020.

Management assurance

In order to assess the effectiveness of the implementation of the internal control, ESA uses the baseline requirements adapted to its environment. The annual assessment for 2019 did not reveal any risks that could lead to a reservation in the Annual Declaration of Assurance.

On the basis of elements of the internal control systems and the assurance they provide – the building blocks of assurance – the Director-General was in a position to sign, as the authorising officer, the Declaration of Assurance which accompanies this Annual Report.



Bohunice NPP in summer © JAVYS

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

Further information

Additional information can be found on the EUROPA website:
<http://europa.eu>

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

More information on the Commission's Directorate-General for Energy can be found at: <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-28 gross and net requirements (quantities in tU and tSW)

(A) 2020-2029

Year	Natural uranium		Separative work	
	Gross requirements	Net requirements	Gross requirements	Net requirements
2020	15 795	13 460	13 037	11 373
2021	16 206	14 931	13 384	12 355
2022	14 684	13 015	12 107	10 895
2023	15 901	13 759	13 248	11 892
2024	13 472	11 503	11 226	9 583
2025	14 912	13 476	12 529	11 304
2026	14 210	12 338	11 861	10 291
2027	14 127	12 005	11 962	10 164
2028	12 906	11 018	10 921	9 299
2029	14 192	11 506	11 887	9 607
Total	146 404	127 010	122 162	106 761
Average	14 640	12 701	12 216	10 676

(B) Extended forecast 2030-2039

Year	Natural uranium		Separative work	
	Gross requirements	Net requirements	Gross requirements	Net requirements
2030	12 353	10 292	10 253	8 479
2031	12 553	10 330	10 479	8 565
2032	12 571	10 466	10 458	8 648
2033	11 861	9 662	9 854	7 961
2034	10 921	8 893	9 054	7 308
2035	11 297	9 095	9 406	7 512
2036	10 110	8 082	8 333	6 587
2037	10 722	8 522	8 889	6 996
2038	10 458	8 430	8 733	6 987
2039	10 425	8 397	8 709	6 962
Total	113 271	92 169	94 169	76 004
Average	11 327	9 217	9 417	7 600

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

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

(*) 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 ₃ O ₈	EUR/kgU	USD/ lb U ₃ O ₈	EUR/kgU	USD/lb U ₃ O 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

Year	Multiannual contracts		Spot contracts		New multiannual contracts		Exchange rate
	EUR/kgU	USD/ lb U ₃ O ₈	EUR/kgU	USD/ lb U ₃ O ₈	EUR/kgU	USD/lb U ₃ O ₈	EUR/USD
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

(*) 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 U₃O₈ price, which includes amended contracts from 2009 onwards.

Annex 4

Purchases of natural uranium by EU utilities, by origin, 2010-2019 (tU)

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Russia	4 979	4 524	5 102	3 084	2 649	4 097	2 765	2 192	1 759	2 543
Kazakhstan	2 816	2 659	2 254	3 612	3 941	2 949	2 261	2 064	1 754	2 518
Niger	2 082	1 726	2 376	2 235	2 171	2 077	3 152	2 151	2 067	1 962
Australia	2 153	1 777	2 280	2 011	1 994	1 910	1 896	2 091	1 909	1 851
Canada	2 012	3 318	3 212	3 156	1 855	2 845	2 946	4 099	3 630	1 485
Namibia	1 017	1 011	1 350	716	325	385	504	923	1 046	1 234
Uzbekistan	459	929	159	653	365	526	115	348	166	612
EU	556	455	421	421	397	412	220	0	18	251
Re-enriched tails	0	0	0	0	0	212	212	171	161	161
South Africa	190	113	412	17	20	1	0	0	118	115
Other	432	128	256	621	299	229	130	80	80	103
United States	320	180	241	381	586	343	125	193	110	0
Ukraine	0	284	0	0	23	0	0	0	19	0
HEU feed	550	731	395	0	0	0	0	0	0	0
Malawi	0	0	180	115	125	2	0	0	0	0
Total	17 566	17 832	18 639	17 023	14 751	15 990	14 325	14 312	12 835	12 835

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
Grand total	228 048	25 002	16 937

Annex 6

EU nuclear utilities that contributed to this report

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

Annex 7

Uranium suppliers to EU utilities

Orano Cycle
Orano Mining
BHP Billiton
Cameco Inc. USA
Cameco Marketing INC.
CNU-SA
Cominak
Energy US
Interexco
Itochu International Inc
KazAtomProm
Macquarie Bank Limited, London Branch
NUKEM GmbH
Quasar Resources
Rio Tinto Marketing Pte Ltd
Tenex (JSC Techsnabexport)
Traxys
TVEL
Urangesellschaft
Uranium One
Urenco Ltd

Annex 8

Calculation method for ESA's average U₃O₈ prices

ESA price definitions

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

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

1. The ESA spot U₃O₈ price is a weighted average of U₃O₈ prices paid by EU utilities for uranium delivered under spot contracts during the reference year.
2. The ESA multiannual U₃O₈ price is a weighted average of U₃O₈ prices paid by EU utilities for uranium delivered under multiannual contracts during the reference year.
3. The ESA 'MAC-3' multiannual U₃O₈ price is a weighted average of U₃O₈ 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 2017 and 31 December 2019) and under which deliveries were made during the reference year. In this context, ESA regards amendments which have a direct impact on the prices paid as separate contracts.

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 U₃O₈ 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 U₃O₈) 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 (U₃O₈, UF₆ or UO₂), 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 with the data collected at the time of conclusion of the contracts, taking into account any subsequent updates. In particular, it compares the actual deliveries with the 'maximum permitted deliveries' and options. Where there are discrepancies between maximum and actual deliveries, clarifications are sought from the organisations concerned.

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 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 ensured by appropriate measures.

Annex 9 Declaration of assurance

I, the undersigned, Agnieszka Kaźmierczak

Director-General of Euratom Supply Agency in 2019

In my capacity as authorising officer

Declare that the information contained in this report gives a true and fair view ⁽⁹³⁾.

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 concerning 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 learnt from the reports of the Court of Auditors for years prior to the year of this declaration.

Confirm that I am not aware of anything not reported here which could harm the interests of the Euratom Supply Agency.

Luxembourg, 31 March 2020



Agnieszka Kaźmierczak

93 True and fair in this context means a reliable, complete and correct view on the state of affairs in the Agency.

Annex 10 Work Programme 2020

Mission and Objectives

In line with the Chapter 6 of 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 EU users.

ESA's strategic objective is the short, medium and long-term 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 objectives have been defined:

Specific policy objectives

1. ensure continuous supply of nuclear materials for EU users;
2. encourage the diversification and emergence of reliable alternative sources of supply;
3. facilitate the continued supply of medical radioisotopes, notably Tc-99m;
4. inform the common supply policy through monitoring and analysis of the nuclear fuel market and relevant R&D activities.

Specific supporting objectives

5. pursue contacts with EU and international authorities and organisations, utilities, industry and nuclear organisations to further the objectives of ESA;
6. improve the effectiveness and efficiency of ESA's organisation and operations.

This work programme sets out the main activities and outputs to be pursued and achieved in 2020. 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 account of the priorities, policies and objectives set out by the Commission.

Areas of activity

Contract management

Since its inception, ESA's main task has been to ensure regular and equal access to supplies of nuclear materials for all users in the EU Member States. To this end, it uses its exclusive right to conclude contracts for supply of nuclear materials, exercises the right of option on nuclear materials coming from inside the Community and monitors 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 continue to

1. conclude nuclear material supply contracts, pursuant to Article 52 of the Euratom Treaty, in line with the common supply policy and the European Energy Security Strategy;
2. acknowledge notifications of transactions involving small quantities, pursuant to Article 74 of the Euratom Treaty;
3. 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 and the European Energy Security Strategy;
4. support the European Commission's nuclear materials accountancy, on request, in verifying contract data contained in prior notifications of movements of nuclear materials;

5. verify, on request, the conformity of draft bilateral agreements between the EU Member States and non-EU countries with the requirements of Chapter 6 of the Euratom Treaty;
6. provide information and support to stakeholders on contract issues related to the UK withdrawal.

Objective: Ensure supply of nuclear materials for EU users		
Main outputs	Indicator	Target
Conclusion of supply contracts submitted	within the statutory deadlines	100%
Acknowledgement of notification of transactions which cover the provision of services in the entire nuclear fuel cycle or involve the transfer, import or export of small quantities of materials		

Facilitating future supply

ESA will shape the common supply policy with the strategic objective of security of supply in order to avoid excessive dependence on any single external supplier, in compliance with relevant decisions at political level and taking due account of the needs of EU utilities.

To facilitate future supply, ESA will:

1. undertake measures to provide market transparency, in particular on the common supply policy pursued by ESA;
2. facilitate emergence of alternative sources of nuclear fuel/services supply where such sources are presently not available, in particular for VVER reactors;
3. review the 'energy security' dimension of the national energy and climate plans (NECP).

Facilitating the continued supply of medical radioisotopes

In order to enhance the security of supply of Mo-99/Tc-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 of nuclear medicine (NMEu)⁽⁹⁴⁾, chairs the European Observatory on the Supply of Medical Radioisotopes.

In line with the conclusions of the report 'Securing the European Supply of 19.75% enriched Uranium Fuel', ESA will also strive to facilitate the future supply of HALEU for production of medical radioisotopes and as fuel for research reactors.

ESA will:

1. lead and coordinate the activities of the European Observatory on the Supply of Medical Radioisotopes;
2. undertake measures that facilitate future supply of HEU and HALEU;
3. contribute to the European Commission's SAMIRA initiative by participation in the Task Force and development of an action plan;
4. encourage (particularly in the context of Euratom framework programmes) projects to secure fuel supply for research reactors and the production of medical radioisotopes.

Monitoring and analysis of developments in the nuclear fuel market and relevant R&D activities

Entrusted with the role of the Nuclear Fuel Market Observatory, ESA will continue to monitor the nuclear market to identify trends likely to affect the EU's security of supply, and to produce analyses and reports.

The Supply Agency's ambition is to retain its position as a reliable and well-respected source of high-quality and neutral analyses of the EU nuclear fuel cycle market it produces.

To deliver on its market monitoring responsibilities, ESA will:

1. monitor and analyse market conditions and technological developments which are likely to have an impact on the nuclear fuel market;
2. conduct the annual survey and deliver the market analysis as part of its Annual Report;
3. support the activities of the Advisory Committee's working groups;
4. continue monitoring the needs for HEU and HALEU which are required to produce medical radioisotopes and to fuel research reactors;
5. publish and disseminate information, including through yearly natural uranium price indices ⁽⁹⁵⁾, reports ⁽⁹⁶⁾, studies, newsletters ⁽⁹⁷⁾, timely updates on ESA's website and through the Advisory Committee or other meetings.

Cooperation with stakeholders and partners

To efficiently carry out its tasks and contribute to security of supply, ESA will actively pursue its relations with EU and Euratom institutions and agencies, Member State authorities, operators, the research community and industry, and international players.

In particular, ESA will:

1. cooperate with the European Commission on common supply policy matters;
2. publish the revised rules that determine the manner in which demand is to be balanced against the supply of ores, source materials and special fissile materials, subject to the approval of the European Commission;
3. liaise with the operators and other concerned parties to encourage and facilitate diversification;
4. in cooperation with the Euratom Member States concerned, coordinate the implementation and seek renewal of the 2014 MoU with the US Department of Energy - National Nuclear Security Administration, in order to ensure HEU supply until full conversion;
5. engage with interested parties in and outside EU, both suppliers and users, to facilitate the continued supply of medical radioisotopes and meet the need of HALEU;
6. monitor the implementation of the Euratom cooperation agreements with non-EU countries as regards trade in nuclear materials;
7. maintain regular contact with:
 - a. international nuclear organisations such as the IAEA and the OECD NEA;
 - b. other international players on the nuclear fuel market, including membership of the World Nuclear Association and the World Nuclear Fuel Market;
 - c. medical radioisotopes supply chain stakeholders (industry, research and user organisations).

95 Multi annual, medium-term, spot and quarterly price indices

96 Quarterly Uranium Market Report

97 Weekly Nuclear News Digest (internal to the Commission)

Making ESA's internal organisation and operations more effective

The Supply Agency keeps its procedures under review to further improve the management of the contracts it receives and the operations of its Nuclear Market Observatory. Given ESA's limited resources, it is of paramount importance to ensure that ESA remains effective and efficient.

To this end, ESA will focus its attention on:

1. developing the new IT system NOEMI (Nuclear Observatory and ESA Management of Information);
2. reviewing ESA's internal control system based on the risk assessment;
3. keeping ESA's work practices under review and updating them where appropriate;
4. reviewing document management policy and expand paperless administration, taking due account of information security;
5. ensuring sound financial management.

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