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EURATOM Supply Agency

ANNUAL REPORT **2018**

Energy

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Foreword

Dear Reader,

I am pleased to present to you the annual report of the Euratom Supply Agency (ESA) for 2018.

2018 was a year of significant advancement for EU energy policy. It saw the conclusion of negotiations on eight major legislative acts aimed at ensuring clean energy for all Europeans.

For the Agency, it was a year of sustained work to carry out its statutory missions whilst dealing with new challenges. ESA continued to assume responsibility for the common supply policy in the interest of regular and equitable access to nuclear material for EU users. In close cooperation with our Advisory Committee, we promoted transparency and predictability in the field, in particular through the activities of the Nuclear Market Observatory.

To ensure security of supply for European users in the medium and long term, we consistently encouraged the diversification of sources. The successful completion of the ESSANUF project marked conceptual progress in developing a viable alternative fuel for VVER-440 power reactors. The Agency welcomes steps towards licensing an alternative fuel supplier in the Member States using VVER technology and encourages continued efforts in this area.

We also pursued our cooperation with the US Department of Energy / National Nuclear Security Agency to implement the HEU exchange programme, as provided for in the 2014 Memorandum of Understanding. The aim is to provide European research reactors and producers of radioisotopes with the necessary amounts of high-enriched uranium (HEU) in conformity with the policy of minimising its use. A dedicated working group of the ESA's Advisory Committee resumed its work on the supply of high-assay low-enriched uranium (HALEU), which currently is not produced in Europe and is destined to replace HEU in nuclear medicine applications as well as in other areas.

2018 was also a year of unique challenges. In preparing for the withdrawal of the United Kingdom from Euratom, the Agency analysed all the supply contracts it had concluded involving United Kingdom entities and took appropriate measures to ensure that those contracts continue to remain valid after the withdrawal of the United Kingdom from the EU. We liaised with the EU-27 stakeholders to help raise awareness of the need to be prepared and addressed, at the appropriate fora, issues related to the future supply of medical radioisotopes.

Over the year, our management team has evolved. Mr Stefano Ciccarello joined the Agency as Head of the Nuclear Fuel Market Operations Unit. Ms Marian O'Leary, who had been leading ESA since 2016, left on well-deserved retirement at the end of 2018.

Following my appointment in January 2019 as Director-General of the Euratom Supply Agency, I took up the position in April. From my first day, the Agency team have supported me with enthusiasm and I already fully appreciate their competency and high level of motivation to accomplish the Agency's mission.

Trusting that the Agency will continue to deliver high-quality work and be respected as an important contributor in its field, I take particular pride in signing the foreword of this first annual report for which I am responsible.

Agnieszka Kaźmierczak

Director-General of the Euratom Supply Agency

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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_3O_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 activities and nuclear energy developments in the EU

ESA operations

Mandate and core activities

The Euratom Treaty (1) created a common nuclear market in the EU. Article 52 of the Treaty established the Euratom Supply Agency (ESA or 'the Agency') to ensure a regular and equitable supply of nuclear fuels to EU users, in line with the objectives of Article 2(d). To this end, ESA applies a supply policy based on the principle of equal access of all users to source materials and nuclear fuel. It focuses on improving the security of supply to users located in the EU, thus also contributing to the viability of the EU nuclear industry. In particular, it recommends that Euratom utilities operating nuclear power plants (NPPs) maintain stocks of nuclear materials and cover their requirements by entering into multiannual contracts that diversify their sources of supply. This is to prevent excessive dependence of EU users on any single supply source from a non-EU country. Diversification should cover all stages of the fuel cycle.

ITER site ©ITER Organization

ESA's mandate is, therefore, to exercise its powers and, as required by its Statutes, to monitor the market to ensure that the activities of individual users reflect the principles set out above. ESA implements the EU common supply policy for nuclear materials by concluding contracts on the supply of nuclear materials coming from inside the Community or from outside. ESA has a right of option on nuclear materials produced in the Member States. Under the Euratom Treaty, ESA also monitors transactions involving services in the nuclear fuel cycle (conversion, enrichment and fuel fabrication). Operators are required to submit notifications, giving details of their commitments, which are acknowledged by ESA.

In 2018, ESA processed 331 transactions, including contracts, amendments and notifications, and thus helped to ensure the security of supply of nuclear materials.

ESA's 2017 annual report was published on ESA's website in June 2018. As every year, ESA presented its annual calculation of different types of average natural uranium prices: MAC-3, multiannual and spot prices. In its 2017 report, ESA included for the second time information about the supply of conversion services to EU utilities. The report is available on the EU Bookshop website in paper and pdf versions (2).

In 2018, in line with its statutory obligations, ESA's Nuclear Fuel Market Observatory continued to publish nuclear news digests, quarterly uranium market reports, price trends and the weekly nuclear news brief (for readers in the European Commission). Greater transparency in the EU natural uranium market reduces uncertainty and helps to improve security of supply.

In 2018, ESA issued four quarterly uranium market reports and provided regular updates of its nuclear news digests. The quarterly uranium market report reflects global and specific

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

(2) https://publications.europa.eu/en/publication-detail/-/publication/bb9a07a2-8eec-11e8-8bc1-01aa75ed71a1/language-en/format-PDF/source-84952635

Euratom developments on the nuclear market. This includes general data about natural uranium supply contracts concluded by ESA or notified to it, a description of the 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.

In 2018 ESA continued to coordinate actions to improve the security of supply of molybdenum-99 (Mo-99) / technetium-99 m (Tc-99 m) — the most vital medical radioisotope — by chairing the European Observatory on the supply of medical radioisotopes (3).

In addition to these activities, ESA was involved in the preparatory work led by the European Commission's Directorate-General for Energy for the development of a 'Strategic Agenda for Medical, Industrial and Research Applications of Nuclear and Radiation Technology' (Samira). A large part of this agenda focuses on aspects of the supply of medical radioisotopes.

Another closely related aspect is the supply of uranium for target fabrication and fuel for the European research reactors where medical radioisotopes are produced. To that end, in close cooperation with the Member States concerned, ESA continued to facilitate the supply of highly enriched uranium (HEU) to users who still need it until their conversion to low enriched uranium (LEU), in compliance with international nuclear security commitments. In 2018, ESA convened a meeting with the US and the Euratom Member States concerned to review progress in implementing the Memorandum of Understanding 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. HEU quantities delivered by the US and those still required by Euratom Member States, as well as HEU quantities shipped and to be transferred to the US for downblending were reviewed. The overall balance, as envisaged by the Memorandum, has been maintained and a significant portion of the materials identified has already been shipped to the US.

As far as 19.75% LEU (high-assay LEU, HALEU) supply is concerned, the ESA's Advisory Committee Working Group was re-instated in 2018 to revisit the 2013 report on whether it would be feasible and appropriate to build European capacity for the production of metallic HALEU (4). The long-term availability and accessibility of HALEU is a key issue, since no appropriate production facilities for HALEU are in place (neither in the EU nor in the US). Without any new initiative, there is a risk for the security of supply of this critically important material after 2030-2040.

Activities of the Advisory Committee

In line with ESA's Statutes, the Advisory Committee assists the Agency 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, as well as Member State governments.

In 2018, the Advisory Committee met twice. At the first meeting on 26 April, the topics on the agenda were the Committee's opinions on ESA's 2017 annual report and on ESA's audited accounts for 2017. The Committee discussed the progress achieved by the Working Group on Prices and Security of Supply, agreed to reinstate the Working Group on European Production of HALEU and formally endorsed its terms of reference. During the meeting, an update was given on ESA's latest discussions on the supply of HEU for research reactor fuel and targets used to produce medical radioisotopes, in the context of the 2014 Memorandum of Understanding on HEU exchanges referred to above. The representatives of Member States presented updates on developments in their countries.

Olkiluoto 3 NPP ©TVO

The second meeting took place on 13 November. The Committee discussed the progress achieved by the two Working Groups: on Prices and Security of Supply and on European Production of HALEU. During the Advisory Committee meeting, the Member State representatives presented updates on developments in their countries and the European Commission's Directorate-General for Energy outlined the main implications for the nuclear fuel supply contracts of the Euratom nuclear cooperation agreements for the peaceful use of nuclear energy. The Committee took note of the updates provided on the draft budget of ESA for the 2019 financial year and on ESA's work programme for 2019. The Committee also provided a favourable opinion on the estimate of ESA's revenue and expenditure for the 2020 financial year.

(3) http://ec.europa.eu/euratom/observatory_radioisotopes.html
(4) http://ec.europa.eu/euratom/docs/ESA-MEP-rapport.pdf

International cooperation

ESA has long-standing and well-established relationships on nuclear energy with two major international organisations: the International Atomic Energy Agency (IAEA) and the OECD Nuclear Energy Agency (NEA). In 2018, ESA continued its cooperation with both these organisations by participating in three working groups: the joint NEA/IAEA Uranium Group ([5]), the NEA Expert Group on Uranium Mining and Economic Development ([6]) and the NEA High-Level Group on the Security of Supply of Medical Radioisotopes (HLG-MR) ([7]).

In July, ESA participated in the NEA Expert Group on Uranium Mining and Economic Development meeting, where the Agency gave a presentation on a case study of a junior mining project in Western Spain. In October, ESA presented its latest analysis of the EU nuclear market at the joint NEA/IAEA Uranium Group meeting. ESA also represented the European Observatory on the Supply of Medical Radioisotopes at the HLG-MR meetings held in February and October 2018.

In April, ESA attended the World Nuclear Fuel Cycle conference co-organised by the Nuclear Energy Institute (NEI) and the World Nuclear Association (WNA). In September 2018, ESA took part in the WNA Symposium ([8]) and the IAEA General Conference ([9]). In October, ESA participated in the OECD/NEA NDC meeting ([10]).

ESA administrative information

The 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 (Article 54 of the Euratom Treaty) and operates under the supervision of the European Commission (Article 53 of the Euratom Treaty) on a non-profit-making basis.

Seat

The seat of ESA has been in Luxembourg since 2004 (Article 2 of the Statutes). Together with the European Commission, the Agency has concluded a seat agreement with the Luxembourg government.

Financing

ESA's present financial situation results from the Council decision (adopted in 1960) to postpone indefinitely the introduction of a charge on transactions (contracts for the purchase of nuclear materials by EU utilities). In accordance with Article 54 of the Euratom Treaty, this charge was intended to cover the Agency's operating costs. Since 1960, therefore, the Euratom Supply Agency has relied on the European Commission, which covers the bulk of the Agency's administrative needs (staff, offices and minor expenses) and additionally grants ESA a financial contribution based on ESA's budget estimate.

Financial Regulation

For its financial operations, ESA applies the relevant provisions of its Statutes as well as the EU Financial Regulation ([11]) and the accounting rules and methods established by the European Commission.

Article 68 of the EU Financial Regulation stipulates that "this regulation shall apply to the implementation of the budget for the Euratom Supply Agency".

Financial accounts and implementation of the budget

In 2018, the assets owned by the Agency totalled EUR 639 600 (EUR 637 046 in 2017). They were financed by liabilities of EUR 13 057 (2%) and equity of EUR 626 543 (98%). The 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 2018, the amount of the instalment called up and reflected in ESA's accounts stood at EUR 585 600.

The Agency's voted budget appropriations for 2018 remained stable at EUR 123 000 (as in 2017). Its revenue and expenditure were in balance. The budget was financed in its totality (EUR 123 000) by a contribution from the Commission budget heading 32.01.07 'Euratom contribution for operation of the Supply Agency' (EUR 123 000 in 2017).

ESA's expenses consist only of administrative costs. The Agency neither manages operational budget lines nor provides grants. The bulk of the Agency's administrative expenses, including salaries, premises, infrastructure, training and some IT equipment, is covered directly by the European Commission budget, and is not acknowledged in the Agency's accounts. 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. This off-budget expenditure and the underlying transactions are included in the EU annual accounts and are considered as non-exchange transactions for the Agency. ESA's running costs are partly covered by its own budget; this includes

(5) http://www.oecd-nea.org/ndd/uranium
(6) https://www.oecd-nea.org/ndd/groups/umed.html
(7) http://www.oecd-nea.org/med-radio/security/
(8) https://static.ptbl.co/static/attachments/190883/1539947593.pdf?1539947593
(9) https://www.iaea.org/about/policy/gc/gc62/2018-09-21
(10) http://www.oecd-nea.org/ndd/ndc/

(11) Regulation (EU, Euratom) 2018/1046 on the financial rules applicable to the general budget of the Union, repealing Regulation (EU, Euratom) No 966/2012 (2012 Financial Regulation) from 2 August 2018.

staff missions, IT equipment for its own computer centre, and media subscriptions.

ESA's budget accounts from 31 December 2018 show a budget execution of EUR 120 344, or 98% of commitment appropriations (against 99% in 2017). Unused amounts are returned to the EU budget.

The budget and final annual accounts are published on ESA's website (http://ec.europa.eu/euratom/index_en.html).

External audit by the Court of Auditors

The European Court of Auditors audits ESA's operations on an annual basis. The Court'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.

In 2018, the Court provided a positive opinion on the reliability of ESA's accounts and on the legality and regularity of the underlying transactions for the 2017 financial year.

Discharge

The European Parliament, acting on a Council recommendation, is the discharge authority for ESA. On 18 April 2018, the European Parliament granted ESA's Director-General discharge for the implementation of the budget for the 2016 financial year ([12]).

Staff

During 2018, ESA's Head of Unit post was filled and ESA's Director General retired on 31 December 2018. At the end of the year, ESA occupied 16 permanent posts. ESA staff are European Commission officials, in accordance with Article 4 of ESA's Statutes ([13]).

EU nuclear energy policy in 2018

A number of measures were taken at EU level in 2018 to implement and further develop the framework for nuclear safety, responsible and safe management of spent fuel and radioactive waste and radiation protection.

Nuclear energy policy

Further to the publication of the latest nuclear illustrative programme (PINC) in 2017 ([14]), the European Commission's Directorate-General for Energy contracted follow-up studies which will contribute in defining priorities in the coming years on the following topics: (i) financial issues of the back-end of the nuclear fuel cycle; (ii) scenarios for long-term operations of NPPs in the EU, also in the context of the EU 2050 long-term strategy; and (iii) benchmarking of nuclear safety technical requirements. The studies are being finalised and results will be available in 2019.

The Directorate-General for Energy provided input to develop the long-term strategy for a climate neutral Europe by 2050 ([15]), building on the analysis of the outlook for the nuclear energy sector performed under the PINC and its related follow-up work. In this context, the European Commission is working to support the development of the most advanced nuclear technologies while ensuring that they comply with the highest level of safety. In particular, the development of small modular reactors (SMRs) – for which the Directorate-General for Energy in cooperation with the Joint Research Centre and the Directorate-General for Research and Innovation is supporting research activities related to aspects such as safety and licensing – may represent a key development for nuclear energy exploitation.

The European Commission initiated discussions on this important topic at the 2018 Bratislava conference of the European Nuclear Energy Forum (ENEF) ([16]), organised by the Directorate-General for Energy in cooperation with the Slovak Ministry of Economy. The conference also addressed the need to maintain a critical level of nuclear safety expertise in Europe.

On nuclear investments, the European Commission's Directorate-General for Energy worked in close collaboration with other services, in particular the Joint Research Centre, the Directorate-General for Research and Innovation, the Directorate-General for Competition and the Euratom Supply Agency, to prepare several Commission opinions on new nuclear energy investments in Europe.

Nuclear safety

In 2018, a key element of the nuclear safety actions performed in Europe was the organisation of the first topical peer review (TPR), as provided for by the 2014 Nuclear Safety Directive ([17]). The review focused on "Ageing management of nuclear power plants and research reactors". Sixteen EU Member States with NPPs and/or research reactors and three non-EU

(12) European Parliament decision of 18.4.2018 (P8_TA(2018)0159, 2017/2168(DEC)).
(13) Council Decision 2008/114/EC, Euratom of 12 February 2008 establishing Statutes for the Euratom Supply Agency (OJ L 41, 15.2.2008, p. 15), and in particular Articles 4, 6 and 7 of the Annex thereto.
(14) https://ec.europa.eu/energy/sites/ener/files/documents/nuclear_illustrative_programme_pinc_-_may_2017_en.pdf
(15) https://ec.europa.eu/clima/policies/strategies/2050_en
(16) https://ec.europa.eu/info/events/13th-european-nuclear-energy-forum-2018-jun-04_en
(17) OJ L 219, 25.7.2014, pp. 42-52.

Member States (Norway, Switzerland, and Ukraine) participated in the TPR.

A peer review workshop took place in Luxembourg in May bringing together 140 experts from EU and non-EU countries. The TPR report and the accompanying country-specific findings were finalised and published in October ([18]). The main conclusion of the TPR is that ageing management programmes (AMPs) exist in all countries with NPPs, and although there are some differences of approach, no major deficiencies were identified in the European regulation and implementation of these programmes at NPPs.

However, the review found that AMPs for research reactors are not regulated or implemented as systematically and comprehensively as for NPPs; challenges remain on the means to evaluate the effectiveness of AMPs; some follow-up actions are necessary to review practices and bring them fully in line with the new IAEA safety standards on ageing management. All regulators have agreed to develop a national action plan by September 2019, addressing the findings of the peer review.

The Commission has continued to support the Member States in transposing and implementing the EU legal framework on nuclear safety.

The European Commission's Directorate-General for Energy – in close collaboration with the Joint Research Centre – also provided support to Member States and nuclear regulators in interpreting and implementing the nuclear safety objective enshrined in the amended Nuclear Safety Directive. As part of a project to promote the practical implementation of the nuclear safety objective, a workshop took place in July 2018 with Member States' nuclear safety regulators, technical experts and nuclear industry stakeholders to discuss i) initial findings from the review of international and European guidance documents and national practices, and ii) the technical areas to be studied in greater detail in the scope of national approaches to implement the Directive's requirements.

In its work on nuclear safety, the European Commission received expert input from the European nuclear safety regulators group (Ensreg) in accordance with its 2018-2020 work programme.

Nuclear decommissioning

In June 2018, the European Commission took important decisions regarding the nuclear decommissioning assistance programmes in Bulgaria, Lithuania and Slovakia ([19]). As part of its effort to prepare the next multiannual financial framework (MFF) for 2021-2027, the European Commission adopted two proposals for Council Regulations to provide continued co-financing for these programmes. In particular, after 2021 the co-funding will enable Slovakia to complete the decommissioning of the concerned reactors and allow Bulgaria to continue advancing in the Kozloduy Units 1-4 decommissioning process in a safe and secure manner until the end of the Kozloduy programme in 2030.The co-funding will also make it possible to support Lithuania to continue safely and steadily to decommission the Ignalina NPP, a first-of-a-kind process where graphite-cores must be dismantled ([20]) ([21]).

In June 2018, the European Commission also adopted a mid-term evaluation on the EU nuclear decommissioning assistance programmes ([22]). It concluded that Bulgaria, Slovakia and Lithuania made effective and efficient progress in decommissioning their NPPs. Based on the revision of the detailed decommissioning plans, the mid-term evaluation report confirmed that no additional funding is needed in the 2014-2020 MFF. However, the need for additional funds in the long term (post-2020) calls for a careful follow-up, especially for the Ignalina programme. In October 2018, the Commission adopted the 2018 annual work programmes and associated financing decisions for the nuclear decommissioning assistance programmes, allocating EUR 141.124 million to implement the actions.

Spent fuel and radioactive waste management

In 2018, the Directorate-General for Energy continued its assessment of the Member States' notified measures, national programmes and first reports on the implementation of the Directive on the Responsible and Safe Management of Spent Fuel And Radioactive Waste ([23]). The Directorate-General for Energy has also started to review the Member States' second reports on the Directive's implementation and should issue its report to the Council and European Parliament on progress and trends in 2019.

In January 2018, the European Commission adopted its second report on the implementation of Council Directive 2006/117/Euratom on the supervision and control of shipments of radioactive waste and spent fuel for 2012-2014 ([24]). The Directorate-General for Energy has also been analysing the third reports by the Member States on this Directive's implementation and should issue the Commission's third report to the Council and European Parliament in 2019.

(18) http://www.ensreg.eu/news/completion-first-topical-peer-review
(19) https://ec.europa.eu/info/news/continued-budgetary-support-nuclear-safety-and-decommissioning-proposed-commission-2018-jun-13_en
(20) https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1528885165785&uri=COM:2018:466:FIN
(21) https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1528899398293&uri=COM:2018:467:FIN
(22) https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1528899280231&uri=COM:2018:468:FIN
(23) OJ L 199, 2.8.2011, pp. 48-56.
(24) https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A52018DC0006

Radiation protection

In 2018, the Directorate-General for Energy continued its assessment of the transposition and implementation of the EU legal framework on the radiation protection of workers and the general public as provided for by the Basic Safety Standards (BSS) Directive ([25]) and the Euratom Drinking Water Directive ([26]).

Five verification visits of Member States' facilities to monitor radioactivity levels were carried out during 2018 under Article 35 of the Euratom Treaty. A number of Commission opinions were delivered on general data submitted by Member States on the plans to dispose of radioactive waste pursuant to Article 37 of the Euratom Treaty. All declarations by Member States under Article 36 of the Euratom Treaty on discharges of radioactive substances into the environment for the year 2017, as per Commission Recommendation 2004/2/Euratom ([27]), had been validated and uploaded in the RADD database (EUROPA website) ([28]).

On nuclear emergency preparedness and response, the Directorate-General for Energy activities – in cooperation with the Directorate-General for European Civil Protection and Humanitarian Aid Operations – focused on the coherent implementation of the BSS Directive and Nuclear Safety Directive requirements, notably at a joint workshop organised with the IAEA in December 2018.

Council Decision 87/600/Euratom ([29]) requires that the Commission and the Member States competent authority test the arrangements for the exchange of urgent information in case of a radiological emergency. On this basis, the last European level annual exercise was organised in November 2018.

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 European Commission's Directorate General for Energy is fulfilling this mandate by implementing a set of controls and verification activities known as Euratom safeguards.

In 2018, 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 European Commission continued to work in close cooperation with the International Atomic Energy Agency 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 provision issued by the European Commission, these documents are at the core of safeguard activities in the EU.

On a wider scope, consideration was given to emerging challenges arising from recent changes in the nuclear industry, from developments in safeguards technology and from the perception of risk. The European Commission addressed these challenges by promoting the use of modern tools and technologies to maximise confidence in the conclusions of inspections, increase overall efficiency while reducing the effort required on-site. Specific attention was paid to preparing for a smooth continuation of Euratom safeguards after the UK's 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.

External dimension of nuclear energy policy

The European Commission's Directorate-General for Energy continued to support the implementation of risk and safety assessments (stress tests) of NPPs in EU neighbouring countries. Work in 2018 focused on the stress tests for the Ostrovets NPP in Belarus. This was a confidence-building exercise that exposed the Ostrovets NPP construction project to the scrutiny of European nuclear safety regulators. The Peer Review Report, endorsed by Ensreg in July, was made public and presented to relevant stakeholders and civil society ([30]).

In support of the implementation of the Joint Comprehensive Plan of Action (JCPoA) with Iran, Commissioner Arias Cañete hosted a high-level seminar for Iranian decision makers, led by the Iranian Vice-President Salehi. The seminar addressed the themes of nuclear international governance, nuclear safety, waste management and international nuclear cooperation. The EU and Iran reaffirmed their commitment to nuclear cooperation under Annex III of the Agreement and agreed on a number of specific activities to be conducted in 2019.

The Euratom Report on the implementation of the Joint Convention on the Management of Spent Fuel and Radioactive Waste ([31]) was presented at the 6th Review Meeting of the

(25) OJ L 13, 17.1.2014, pp. 1-73.
(26) OJ L 296, 7.11.2013, pp. 12-21.
(27) https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:002:0036:0046:EN:PDF
(28) http://europa.eu/radd/
(29) https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31987D0600:EN:HTML
(30) http://www.ensreg.eu/sites/default/files/attachments/hlg_p2018-36_155_belarus_stress_test_peer_review_report_0.pdf
(31) https://ec.europa.eu/energy/sites/ener/files/documents/jc_euratom_report_2018.pdf

Contracting Parties to the Convention, which took place in Vienna from 21 May to 1 June 2018.

The close collaboration at all levels with international agencies continued during 2018, in particular with the IAEA in Vienna and the Nuclear Energy Agency (NEA) in Paris.

ITER

In April 2018, the Council of the EU adopted Conclusions mandating the European Commission to approve the new baseline at an ITER Council meeting at Ministerial level, responding to the Commission Communication of June 2017 on the newly defined 2016 baseline for the ITER project.

On this basis, in May the European Commission proposed to allocate EUR 6.07 billion to finance the European participation in ITER for the next MFF. In June, the Commission adopted a specific legislative proposal for the implementation of this funding in the next MFF. Funds will be used to complete the construction and finalise the assembly of the fusion machine in order to begin operations after First Plasma, scheduled for December 2025.

On the ITER site ([32]), construction is steadily progressing - the physical construction activities for First Plasma surpassed 60% completion by the end of 2018. Fusion for Energy (F4E) ([33]) - the EU domestic agency that implements the EU contribution to the project, made significant progress in the construction of ITER buildings, completing the concrete crown (base) of the tokamak on schedule in August 2018. The manufacturing of toroidal magnets and their insertion into precision-fabricated cases is well advanced in Europe and Japan. Overall, substantial progress is being made for every major ITER component, system and structure.

A new administrative agreement between the Commission and F4E was signed at the end of 2018. It sets out the conditions for the transfer of funds from the European Commission to the Joint Undertaking, improving the practices and instruments for the steering and supervision of F4E, and complements the supervision strategy for Euratom's participation in the governance of the ITER Organisation.

The European Commission's Directorate-General for Energy also coordinated the Euratom's contribution to three projects (IFMIF/EVEDA ([34]), JT-60SA ([35]) and IFERC ([36])) carried out under the "Broader Approach" Agreement with Japan. Significant progress in these projects was achieved in 2018.

European Commission research and innovation programmes

On 7 June 2018, the European Commission presented its EUR 100 billion proposal for the new research and innovation programmes for the next long-term EU budget covering 2021-2027.

A new programme – Horizon Europe ([37]) – will build on the achievements and success of the previous research and innovation programme (Horizon 2020) and keep the EU at the forefront of global research and innovation. Horizon Europe is the most ambitious research and innovation programme ever. The proposed budget for Horizon Europe is EUR 97.6 billion.

The Euratom research and training programme ([38]), which funds research and training on nuclear safety, security/safeguards/non-proliferation, radioactive waste management, decommissioning, radiation protection, research infrastructures, education and training and fusion, will have an increased focus on non-power applications, such as healthcare and medical equipment, and will also support the mobility of nuclear researchers under the Marie Skłodowska-Curie Actions. In addition, the supply and use of radioisotopes for medical uses remains one of the areas of action of the proposed Euratom 2021-2025 research and training programme.

The proposal for the Euratom 2021-2025 programme earmarks a total budget of EUR 1.675 billion for research activities on fusion and fission. Around EUR 724.5 million are dedicated to fusion research activities and around EUR 950.5 million to fission research activities. The fission research activities are implemented through both the indirect actions (budget of around EUR 331 million) of the Directorate-General for Research and Innovation and the direct actions (budget of around EUR 619.5 million) of the Joint Research Centre.

In December 2018, the European Commission adopted the Euratom 2019-2020 work programme. This work programme also serves as a 'bridge' between the ongoing Euratom programme and the expected future Euratom programme in 2021. A total of EUR 133.9 million spread across 17 topics is dedicated to fission research activities under the heading NFRP-2019-2020.

This work programme includes two topics related to the activities of the Euratom Supply Agency. The first topic with EUR 7.5 million (named "NFRP-15: Optimised fuels for production of medical radioisotopes") focuses on increased safety in the qualification phase of fuel elements based on LEU, which is key to ensure the secure supply of fuel and targets for research reactors in compliance with the Euratom's international

(32) https://www.iter.org/
(33) https://f4e.europa.eu/
(34) https://www.ifmif.org/
(35) http://www.jt60sa.org/
(36) http://www.iferc.org/
(37) https://ec.europa.eu/info/designing-next-research-and-innovation-framework-programme/what-shapes-next-framework-programme_en
(38) https://ec.europa.eu/programmes/horizon2020/en/h2020-section/euratom

commitments on non-proliferation. This action is expected to sustain the EU's capacity to produce medical radioisotopes by ensuring the availability of high-performance research reactors.

The second topic with EUR 1.1 million (named "NFRP 17: Optimised use of European research reactors") will support networking activities for the largest possible number of research reactor operators at European level in order to facilitate the exchange of information on the availability of research reactors to meet research and radioisotopes production needs across Europe.

European Commission Joint Research Centre activities

The European Commission implements the Euratom research programme through direct and indirect actions. The direct actions concern research carried out by the European Commission through the European Commission Joint Research Centre (JRC) and are focused on nuclear safety, radioactive waste management and radiation protection, safeguards and security, including support for the relevant EU policies. The indirect actions concern research carried out by trans-European project consortia of private and public research groups. They address not only the safety of nuclear systems, waste management and radiation protection, but also the feasibility of fusion as a power source.

The core of the JRC programme is supporting Member States in the different areas of nuclear safety, safeguards and security. The JRC conducts the Euratom direct actions on its different nuclear sites through a biennial rolling work programme revised every year. After a planning phase performed by the JRC, the work programme is sent via inter-service consultation for comments from other Commission departments, and to the JRC Board of Governors (composed of representatives from Member States and associated countries) for its opinion. Once their feedback has been received and processed, the programme is formally adopted in a Commission implementing decision.

The JRC runs an acknowledged research programme on nuclear reactor safety, nuclear fuel safety in power reactors operating in the EU, and the safe operation of advanced nuclear energy systems. In addition to research in the field of waste management, JRC is developing new projects in the field of nuclear decommissioning.

To implement the EU safeguards system, the JRC developed methods, techniques and standards and operated the on-site laboratories located in reprocessing plants (France and UK), on behalf of the Euratom safeguards authority. JRC also provided technical support during safeguards inspection campaigns and continued its support to IAEA under the European Commission support programme; more than 40 technical support projects are now being implemented.

In the field of nuclear security, JRC provided technical assistance and training to Member States and IAEA; the JRC established the European Nuclear Security Training Centre (EUSECTRA) ([39]) to train the officers, coaches and experts on detection, forensics and response to illicit trafficking of radioactive materials. EUSECTRA is also used for hosting and organising international nuclear exercises with partners such as IAEA, the Global Initiative to Combat Nuclear Terrorism (GICNT), the United States and Japan.

The JRC scientific laboratories and facilities are open to European scientists. The two JRC initiatives, Actinide User Laboratory (ActUsLab) ([40]) and European research infrastructure for nuclear reaction, radioactivity, radiation and technology studies in science and applications (EUFRAT) ([41]) are contributing in maintaining and developing nuclear skills in Europe.

In parallel, the JRC provided technical support for the European Commission's follow-up of the implementation of the Nuclear Safety Directive (JRC hosted the secretariat for EU 'stress tests' requested by the Council following the Fukushima nuclear accident, gave support for the recent topical peer review exercise). JRC also provided technical support to help implement the Council Directive for the Responsible Management of Irradiated Fuel and Radioactive Waste.

For radiation protection, the JRC developed the European-wide environmental radioactivity monitoring systems and supported harmonisation of national monitoring processes. The EU added value is demonstrated in activities such as management of the European Community Urgent Radiological Information Exchange (ECURIE) ([42]), management of the European Radioactivity Data Exchange Platform (EURDEP) ([43]) as well as metrology for radioactivity, which includes developing and producing dedicated reference materials.

The JRC collaborates with the Euratom Supply Agency on the security of supply of medical radioisotopes. Among other initiatives to support research on new uses of radioisotopes in therapy and research on alternative radioisotope production technologies, the JRC is active in assessing the EU market of medical radioisotopes, in order to better understand the EU landscape, stakeholders and present and future needs. In 2018 the JRC conducted a study on this topic (Sustainable and Resilient Supply of Medical Radioisotopes – SMER), in reply to a request by the Council of the EU for such an initiative from the European Commission. This study, and its follow-up in 2019 (on therapy-related radioisotopes), is supporting the JRC's contribution to the European Observatory on the Supply of Medical Radioisotopes, and its contribution to the EU strategic agenda for medical, industrial and research applications

(39) https://ec.europa.eu/jrc/en/european-nuclear-security-training-centre-eusectra
(40) https://ec.europa.eu/jrc/en/page/actinide-user-laboratory-actuslab
(41) https://ec.europa.eu/jrc/en/eufrat
(42) https://webgate.ec.europa.eu/ecurie/About.aspx
(43) https://remon.jrc.ec.europa.eu/About/Rad-Data-Exchange

of nuclear and radiation technology (Samira), and for international cooperation with, for example, the NEA or the IAEA.

Main developments in the EU

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 pursuant to Article 50 of the Treaty on the European Union.

On 14 November 2018, the EU-27 Member States and the UK agreed, at negotiators' level, on a "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", which was subsequently endorsed at the extraordinary European Council of 25 November. A joint political declaration setting out the framework for their future relationship was also agreed between the EU and the UK, at negotiators' level.

At the end of 2018, the withdrawal agreement was still due to be ratified by the EU and the UK pursuant to their respective procedures applicable. The agreement provides for a transition period, starting on the date of its own entry into force and ending on 31 December 2020, during which, subject to exceptions, EU and Euratom Law will remain applicable to and in the UK.

According to the joint political declaration, the future relationship "should include a wide-ranging Nuclear Cooperation Agreement" between Euratom and the UK on peaceful uses of nuclear energy. In the same document, the parties noted that ESA "intend[ed] to reassess in a timely manner the authorisations and approvals of contracts for the supply of nuclear materials" between EU and UK undertakings, which it has co-signed. The parties also stated that they would cooperate, through the exchange of information, on the supply of medical radioisotopes.

As shown in Table 1, at the end of 2018 a total of 126 nuclear power reactors of different designs were in operation in the EU, producing 25.2% of its electricity (44). Five reactors were under construction, as official construction works started in the UK, at the Hinkley Point C-1 reactor.

No significant progress was made during 2018 on the new uranium mining projects in Finland and Spain. On nuclear plant construction, the on-going projects in France, Finland and Slovakia encountered some delays, while two of the planned projects in the UK were abandoned.

Table 1. Nuclear power reactors in the EU in 2018

Country	Reactors in operation (under construction)	Net capacity (MWe) (under construction)
Belgium	7	5 918
Bulgaria	2	1 966
Czechia	6	3 930
Germany	7	9 515
Spain	7	7 087
France	58 (1)	63 130 (1 650)
Hungary	4	1 902
Netherlands	1	482
Romania	2	1 300
Slovenia/Croatia (*)	1	688
Slovakia	4 (2)	1 814 (880)
Finland	4 (1)	2 784 (1 600)
Sweden	8	8 622
United Kingdom	15 (1)	8 918 (1 630)
Total	**126 (5)**	**118 056 (5 760)**

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

Source: World Nuclear Association (WNA) and EU Member States.

(44) Eurostat Energy Statistics, 2017.

In several EU countries, the focus was on revising national energy strategies or programmes and investing in research and innovation on the use of nuclear energy for medical purposes or for the new generation of reactors.

Regulatory approval was granted to extend the operational lifetime of two nuclear power reactors in Finland, and preparatory work on having lifetime extensions was initiated to some extent in Spain and Romania. Decisions on operating lifetimes depend on current and projected electricity market conditions, as well as social and political factors. Work continued on the projects for the safe management of spent fuel and radioactive waste. No reactor was taken off the grid in the EU in 2018.

Country-specific developments in 2018

Belgium: In an updated energy strategy released on 30 March, the Federal Government confirmed that all nuclear reactors in Belgium would permanently shut down by the end of 2025, with Doel-3 offline by 2022 and Tihange-2 by 2023. The strategy calls for increased funding for renewable energy, primarily offshore wind power. Currently, renewable power generation in Belgium comprises only about 15% of the country's electricity mix.

In September, the Council of Ministers approved EUR 558 million in funding for 2019-2038 for the multipurpose hybrid research reactor for high-tech applications (Myrrha), the accelerator-driven research reactor at the Belgian Nuclear Research Centre's (SCK-CEN's) site in Mol. Construction of the Myrrha reactor itself is expected to begin in 2026, with full-operation from 2033. Myrrha is intended to replace Belgium's ageing BR2 research reactor, and will be used for various purposes, including scientific research in areas such as nuclear physics, atomic physics, fundamental interactions, solid-state physics and nuclear medicine. The country also decided in 2018 to invest in research on non-fission methods used for medical radioisotope production.

On 17 October, Belgium and China signed a framework nuclear cooperation agreement to develop closer cooperation in technology and innovation. Early November, Belgium donated EUR 2 million to the EU-supported plan for environmental remediation of legacy uranium mines in Central Asia.

Bulgaria: Pursuant to the recent European legislative framework, Bulgaria is finalising its draft national integrated climate and energy plan to be submitted to the European Commission. Following the enshrined priorities of the plan, nuclear energy is to continue having a role in the future national energy system.

Based on 2018 decisions of the National Assembly and the Council of Ministers, the Bulgarian authorities have resumed exploring the possibilities of implementing the Belene NPP project together with a strategic investor, based on market principles ([45]). The analysis and procedure for selecting the strategic investor are ongoing. As regards the Kozloduy NPP Units 5-6 operation, activities relating to the licence renewal application for Unit 6 continued during 2018, as the reactor's 30-year design lifetime ends in October 2019. Unit 5 has already obtained a 10-year licence extension with a possibility to be operational to 2047.

On the decommissioning programme of Kozloduy NPP Units 1-4, tangible progress has been made in terms of material free-release and dismantling activities both in the turbine hall and reactor buildings. In particular, the conceptual design was approved for dismantling Unit 1 primary circuit equipment and components in the reactor building. Some 120 hours of active commissioning tests were completed as part of the commissioning process for the plasma melting facility intended to treat solid waste with a high volume reduction factor.

Czechia: A new atomic law was adopted in 2018, meaning that by the end of 2019 new regulations have to be implemented and laws revised. There is strong public and political support across the country for the two new build projects, but there is no definitive schedule or financing plan.

Based on the results of a study conducted in March 2018 for the Ministry of Industry and Trade, the country must have new NPPs built if it wants to meet the EU's energy roadmap carbon-cutting goal of reducing emission levels by 80% by 2050 from 1990 levels. Renewable energy and an increased use of natural gas alone are deemed unable to cover domestic demand and maintain a national electricity supply surplus. The goal is to achieve 50% of electricity output from nuclear. Were the four units at the Dukovany NPP to close early, between 2025 and 2027, the country would be faced with an electricity deficit. As for the timescale for the Temelin project, some delays have been encountered, and the new units should be built by 2035 to replace the oldest Dukovany units.

According to the findings of a technical and economic study carried out by ČEZ on the long-term operation (LTO) of its NPPs, there are no fundamental technical or safety-related obstacles to a 60-year operating lifetime for the two units at the Temelin NPP. The study confirms the feasibility of the Temelin-1 unit's LTO until 2060 and for the Temelin-2 unit until 2062, and notes that the units could smoothly continue to operate even beyond those dates. The 1013 MW units were initially given a 30-year operational lifespan, until 2020 and 2022, respectively. The policy document, however, warns that the average operational lifetime for European reactors is 50 years.

New improved fuel from Russia was loaded at the Temelin NPP during 2018, and ČEZ expects to also load fuel from Westinghouse by early 2019.

(45) No long-term contracts for mandatory purchases of electricity, no preferential prices or contracts for differences and no corporate or state guarantees.

Germany: In May, the government passed a law setting limited compensation for nuclear operators, after a court ruled that parts of the country's 2011 nuclear phase-out bill were unconstitutional. The final closure dates for the seven German reactors still in operation remains the end of 2022, when Germany will fully exit nuclear power generation. Under the new law, nuclear power operators will be allowed either to sell to other operators the government-allocated nuclear power production quotas which they were unable to produce before closure, or to receive appropriate government compensation in 2023, based on the then applicable power prices. In addition, nuclear operators can submit claims for so-called "frustrated" investments made at NPPs between October 2010, when a law extending the allowable operating time of nuclear units was passed, and March 2011 when that law was reversed following the Fukushima accident.

The 2016 government decision on managing the back-end operations was implemented in 2018. According to the decision, waste and spent fuel will be managed only by the state, with contributions by operators. The remaining operations are still the responsibility of the companies. The dedicated waste management state companies were created and have now started their activities; it is estimated that by the end of 2019 full responsibility for waste will be transferred to them, in accordance with the new law.

Spain: In August, the government outlined the key energy policy objectives in accordance with the integrated national energy and climate plan, to be approved in 2019. Within this framework, a draft energy transition bill published in November includes a target of sourcing 70% of electricity generation from renewables by 2030, increasing to 100% renewable generation by 2050.

On the Salamanca mine project managed by Berkeley, no significant progress has been made since 2017. The granting of the construction licence is still pending.

In relation to the back end of the Spanish nuclear fuel cycle, the government has decided to stop the licensing process for the centralised waste storage facility until the energy mix is established by the national integrated energy and climate plan.

Estonia: The country continued decommissioning the old reactor components, and a repository is now needed to store waste and components. An interim storage facility currently exists on site for all the radioactive waste produced in Estonia. In 2016 it was decided that a final repository would be built by 2040. The government should provide funding during 2019-2022, and an environmental impact assessment (EIA) for the site selection is also expected to start in 2019. Three sites have already been preselected and, following a public consultation, there is a preference for locating the repository on the site of the previous reactor. The choice seems to be the best one in terms of geology, but the EIA needs to be conducted before any final decision can be taken.

France: On 23 January 2018, New Areva announced it had been renamed Orano: its activities encompass mining, conversion, enrichment, used fuel recycling, nuclear transportation and storage, decommissioning and dismantling, nuclear waste management, support to operations and engineering. AREVA NP officially changed its name back to Framatome, following the acquisition of a 75.5% stake by EDF. Mitsubishi Heavy Industries (MHI) and Assystem have in the meanwhile acquired the remaining shares, 19.5% and 5%, respectively. The newly created Framatome includes most of the reactor business formerly owned by AREVA, including the fuel fabrication business, except for contracts for the Olkiluoto EPR in Finland and certain contracts related to the Le Creusot forge facility, which remain under AREVA SA.

In July, EDF announced that the Flamanville 3 EPR would not start loading fuel until the fourth quarter of 2019, and not during the summer of 2019, as previously anticipated. The company also declared a EUR 400 million increase in construction costs.

In May and July, EDF signed contracts for the recycling of reprocessed uranium (RepU) for use in PWR. Recycling is to begin in 2023. This solution enables EDF to diversify its uranium supply sources, allowing for savings of around 10-15% of its natural uranium requirements. It also ensures completeness of the French nuclear cycle by reusing 96% of the nuclear material contained in spent fuel.

Orano's Comurhex II facilities (now named Philippe Coste) were officially inaugurated on 10 September. At the Malvesi site, the first conversion step, from U_3O_8 to UF4, has been fully operational since 2016. The Tricastin site (conversion from UF_4 to UF_6) is expected to start operations during 2019, with a progressive ramp-up to reach full production in 2021 (15 000 tU/year).

During 2018, the Alternative Energies and Atomic Energy Commission (CEA) signed an agreement with the US Department of Energy (US-DOE) for cooperation in the research and development of fast sodium-cooled reactor technologies, in areas such as computer modelling and simulation, as well as validation and technology testing. The agreement will also cover access to the supply chain, experimental facilities in the US and France and advanced materials R&D.

At the end of October, it was reported that EDF had informed ASN of its intention to close Unit 1 at the Fessenheim NPP by 2020, and Unit 2 by 2022. On 27 November President Emmanuel Macron presented the country's future energy mix plan until 2028 (PPE). On nuclear energy matters, the draft PPE specifies the objective of reducing nuclear energy's share of the French electricity mix to 50% by 2035. The PPE requires EDF to close 14 of its 58 reactors by 2035, including the two reactors in Fessenheim. Regarding nuclear new build, the French government has decided to keep the option open for the long term, and to carry out a working programme addressing the industrial, financial and regulatory issues. Conclusions will be drawn in 2021 before any potential decision is made.

Hungary: The tender for extending the cooling canal system at Paks NPP, a key safety investment, was declared invalid in September 2018, which will further delay the project, already behind schedule by at least 2 years.

In its 2019 work programme, the Hungarian Atomic Energy Authority (HAEA) declared it does not expect to receive a final construction permit application in 2019 for the planned two new units at the Paks NPP, a potential further delay of a year for a project that is already behind schedule. The state-owned Paks II project company was expected to submit such an application already in 2018. The HAEA has 15 months to review a permit request for new nuclear units, meaning that if no request arrives during 2019, the first pouring of concrete is unlikely to occur before 2021.

Italy: In early 2018, the dismantling of JRC's ISPRA 1 reactor was assigned to Sogin, which is currently working on covering the plant and collecting data needed for the project. The positive results of the technical review conducted by IAEA on the dismantling of Trillo and Garigliano NPPS were announced during the September General Conference. On 25 October, the government approved a draft agreement for managingf nuclear waste from the Ispra reactors.

Lithuania: In February 2018, the last spent fuel was unloaded from the reactor of Ignalina NPP's Unit 2. The reactor is now completely defueled.

The Netherlands: On 14 March, Framatome reported that it had completed a comprehensive modernisation of the instrumentation and control technology at the EPZ' Borsselle NPP. Initiated in 2014, the project included the installation of new reactor control and limitation systems to monitor the operation of the plant and to safely shut down the reactor if any deviations were detected.

Poland: In November, as part of a new "US-Poland Strategic Dialogue on Energy", the US DoE and Poland's Ministry of Energy signed an agreement on closer cooperation, covering nuclear energy, cyber security, fossil energy and energy infrastructure. According to a draft energy policy document entitled Polish Energy Policy until 2040, made public by the Ministry of Energy on 23 November, the country's first NPP should be in operation by 2033. The policy aims to reduce coal's share of Poland's energy mix from the current 80% to 30% by 2040, and to increase the share of renewable energy to 21% by 2030. Between 6 and 9 GWe of nuclear capacity is expected to be added by 2043, accounting for about 10% of Poland's electricity generation. Site characterisation work and technical studies on site selection and evaluation of the proposed nuclear project were underway.

Romania: In May, it was decided that the 706-MW Cernavodă-1 Candu heavy water reactor unit would be shut down for refurbishment in 2026, as part of the activities to extend the plant's operating lifetime. In 2016, the Romanian government expressed its intention of establishing a joint venture with China General Nuclear Corp. (CGN) to complete the construction of the Cernavodă-3 and -4 units, but discussions between the government, CGN and Nuclearelectrica have not been completed.

In May, the European Commission announced that it had opened an in-depth investigation to assess whether Romania's various public support measures for the National Uranium Company, known as Compania Natională a Uraniului SA (CNU), are in line with European Union rules on State aid. At the end of October, the Organization for Canadian Nuclear Industries announced that it had signed a memorandum of understating with the Romanian Atomic Forum Association (Romatom), providing for cooperation in nuclear supplies.

Slovakia: In July, Slovenské Elektrárne reported that Unit 3 of Mochovce NPP would become operational in the second quarter of 2019, slightly later than previously estimated. In August, the company announced that cold hydraulic testing at the unit, performed to check the leak-tightness of plant systems and components, had been completed, marking a key milestone in the commissioning process for the reactor. During 2018 the Slovak parliament approved a law on a national decommissioning fund, destined to cover all the back-end activities: decommissioning and costs of interim and final storage of spent fuel. The necessary secondary legislation on the operators' financial participation, for future spent fuel, but also to cover historical deficit, is under preparation.

In IAEA's dedicated country review report released in November, Slovakia was praised for generating 80% of its electricity from low-carbon power sources. Nuclear power is responsible for producing around 55% of the country's electricity. On 10 December, Slovenské Elektrárne signed an agreement with the European Investment Bank for a EUR 60 million loan to improve safety measures at its four operating VVER-440 reactors.

Finland: On 11 March, TVO officially declared that it had signed a settlement agreement with Framatome, Siemens AG, and AREVA SA concerning the Olkiluoto 3 (OL3) EPR project in Finland. The agreement covers several issues, including ensuring that there are adequate technical, human, and financial resources to complete the project. At the end of November, TVO announced that the OL3 NPP is expected to start commercial operation in January 2020 instead of September 2019, as previously scheduled.

In September the Finnish Ministry of Economic Affairs and Employment approved a 20-year extension of the operating licenses for the 910-MW Olkiluoto-1 and the 890-MW Olkiluoto-2 units, operated by TVO. The previous operating licenses for the units were due to expire at the end of 2018. TVO can now also store in its repository small amounts of radioactive waste generated by Finnish healthcare, industries and research institutions.

On 21 December, the Fennovoima consortium announced that, according to a revised provisional schedule provided by Rosatom, commercial operation of the projected Hanhikivi NPP had been delayed by 4 years, to 2028 instead of 2024. The change takes account of the delay, caused by incomplete documentation provided by the contractor, in the granting of a construction license by Finland's nuclear regulator, STUK, expected in 2021 instead of 2019.

The country's research reactor is being decommissioned, and Posiva is now building the final repository in Olkiluoto, with additional testing having been successfully performed.

The Terrafame nickel mine is currently waiting for its uranium extraction licence.

Sweden: Among the 8 operating reactors, 6 are in the process of being upgraded with independent core cooling systems, as required by the Swedish Radiation Safety Authority in the aftermath of the Fukushima accident. In the approval process for the final storage of spent fuel, additional questions delayed the decision expected by the end of 2018. A bill was approved, providing that by 2040 production of energy from renewable sources will reach 100%. The bill states the ambition for renewables and is not a closing date for nuclear.

United Kingdom: In March, officials from EDF Energy confirmed that, where it is safe and commercially viable to do so, the company would seek to obtain extensions for the operating lifetime of all nuclear power stations in the UK.

On 27 June, the UK Department of Business, Energy & Industrial Strategy announced the signature of a sector deal with the nuclear industry for more than GBP 200 million in funding. The deal involves cooperation between the government and industry to reduce the cost of building new reactors by 30% by 2030 and to cut decommissioning costs by up to 20%. The funding also targets fusion technology, support for training and skills development and an increased female participation in the civilian nuclear sector to 40% by 2030.

In July, the General Court of the European Union approved the UK government's plan to provide financial support to EDF Energy and its subsidiaries to build the two nuclear power stations at Hinkley Point C in western England with a total capacity of 3 200 MW. In September, EDF Energy reported that the project was on track for its next major milestone in 2019 – the completion of the 4 500 tonne concrete platform on which the reactor buildings sit. The first unit is scheduled to come online in 2025.

As for the other ongoing new reactor build projects, they have either been suspended or terminated. Horizon announced that it will suspend its UK nuclear development programme, following a decision by its parent company Hitachi. The NuGen AP-1000 project has been terminated, as Toshiba has pulled out of the project. The Moorside site will go back to government ownership.

During 2018, the UK government ratified a previously signed agreement for cooperation in the development of Generation IV nuclear technology. The agreement enables the UK to collaborate with other participating entities, such as Euratom, the United States, China, Canada, France, Japan, Russia, South Korea, South Africa, Argentina, Brazil, Australia, and Switzerland, in Generation IV nuclear technology research and development programmes.

Reprocessing of spent fuel officially ended at Sellafield Ltd's Thorp plant, operational since 1994. Thorp will continue to be used until the 2070s as a storage facility for spent fuel. At the end of 2018, the UK published a policy paper called *Implementing Geological Disposal: Working with Communities: An updated framework for the long-term management of higher activity radioactive waste*, thus launching a new search for a site to host the country's proposed geological disposal facility for high-level radioactive waste.

On 2 November, the UK signed a bilateral nuclear cooperation agreement (NCA) with Canada. According to the UK Department of Business, Energy and Industrial Strategy, the UK has now signed all the international agreements required for nuclear commerce to continue after the Brexit process is completed. The UK Parliament should soon ratify the NCAs signed with the United States, Canada, and Australia so that nuclear trade can continue after withdrawal from the EU and Euratom.

2. World market for nuclear fuels

This chapter presents a short overview of the main developments in 2018 that affected the global supply and demand balance and the security of supply at different stages of the fuel cycle. It relies on data collected from various specialised publications.

According to the IAEA[46], on 31 December 2018 there were 454 nuclear reactors operational in 30 countries, with a capacity to generate 400 GWe and supply about 11% of the world's electricity. World nuclear power generation increased by 8 GW(e) compared to 2017, with the new generation capacity coming from China. Nine new nuclear reactors were connected to the grid in 2018 while construction started on another five, and three reactors were shut down. Expansion, as well as near and long-term growth prospects, remains centred in Asia, home to 35 of the 55 reactors under construction at the end of 2018 .

According to projections released in May by the International Energy Agency (IEA), nuclear power is still expected to meet its 2020 Sustainable Development Scenario (SDS) assumption of 438 GWe of installed capacity. However, the 2025 target of 490 GWe of capacity is no longer considered attainable, and the nuclear phase-out policies in South Korea, Germany, Belgium, and Taiwan are expected to lead to the closure of 25 GWe of the current capacity. The use of accident-tolerant fuels could potentially help to achieve the SDS targets.

Mid-September, the IAEA published its *Climate Change and Nuclear Power 2018*[47] report, which includes the latest scientific information and analyses on the link between energy production and climate change. Nuclear power is seen to play a very significant role in combating climate change, while at the same time providing the increasing quantities of electricity needed for global economic development.

On 28 November, the European Commission adopted a strategic long-term vision for a competitive and climate neutral economy by 2050, called *A Clean Planet for All*[48]. The European energy system will need to decarbonise by 2050, when, according to this strategy, 80% of electricity will be coming

Mulga Rock Uranium Project in Western Australia ©Vimy Resources Limited

from renewable energy sources and about 15% from nuclear power. In early December the EU Council approved a series of new targets for reducing emissions. The ministers also signed off a new EU governance regulation, which sets out how the European Commission will monitor and coordinate progress in achieving those targets.

At the end of 2018, China had 46 nuclear power reactors in operation and 11 under construction. Unit 1 of Taishan NPP, the first 1 650-MW EPR in the world, was connected to the grid in June and started commercial operation on 13 December. Unit 1 of the Sanmen NPP, the world's first Westinghouse AP1000, entered commercial operation in September. The adjacent Sanmen 2 attained initial criticality in mid-August and started commercial operation in November. China completed the preliminary design of the Yanlong low-temperature reactor (DHR-400), designed to provide district heating, which could be built at either inland or coastal sites and has a designed lifespan of around 60 years. On 27 November, China National Nuclear Corp (CNNC) officially opened a new centre for nuclear fuels and materials research in Beijing, seen as an important step towards China's innovation-driven strategy to build and develop an advanced nuclear science industrial system.

On 3 July, Japan's Cabinet reportedly approved a revised basic energy plan, laying out the country's mid- and long-term energy policy. Under the plan, nuclear energy is expected to account for 20-22% of Japan's overall energy supply in 2030,

(46) Nuclear Technology Review 2019.
(47) https://www-pub.iaea.org/books/iaeabooks/13395/Climate-Change-and-Nuclear-Power-2018
(48) http://europa.eu/rapid/press-release_IP-18-6543_en.htm

which would require 30 operating nuclear reactors. In a November press release, Japan's Ministry of the Economy, Trade, and Industry announced the signature of a memorandum of cooperation with the US Departments of Energy and Commerce for enhanced nuclear power cooperation, in areas such as research, development and industrial cooperation, as well as decommissioning and back-end fuel cycle management. At the end of 2018, Japan had restarted nine reactors.

In March, Nuclear Power Corporation of India Limited (NPCIL) and EDF signed an agreement on the construction of the planned Jaitapur NPP, comprising six EPR reactors with a combined total capacity of nearly 10 GWe, which could become the world's largest nuclear power generation facility. In April the Indian government announced that the country had reduced its target for the construction of new nuclear capacity to 22 480 MW by 2031, down from the previous target of 63 000 MW as set by the Integrated Energy Policy of 2006. India would have to bring 9 000 MW of nuclear capacity online between 2024 and 2030 in order to meet the new goal. In October, it signed an agreement with the Russian Federation for cooperation in new nuclear projects, covering the development of six reactors at a new plant site in India, potential new technologies, and joint efforts for nuclear projects in other countries.

Philippe Coste conversion plant at Tricastin site ©ORANO

While there are plans for a number of new reactors in the US, no new units were connected to the grid in 2018. In the beginning of the year, EnergyFuels and UrEnergy filed a petition with the US Department of Commerce (DoC) under Section 232 of the Trade Expansion Act of 1962, seeking an investigation into the effects of uranium imports on US national security, and calling for limits to imports to reserve 25% of the US nuclear market for domestic uranium production. The investigation is ongoing. Florida Power & Light became the first US utility to submit an application to the US Nuclear Regulatory Commission (NRC) for a second licence renewal, which would allow its two Turkey Point units to operate for 80 years, until 2052 and 2053, respectively. NRC is expected to complete its review within 18 months. Operators of three other NPPs have declared their intentions to submit a so-called subsequent licence renewal application. In June, NRC approved the indirect transfer of Westinghouse's fuel fabrication facility and export licenses to an affiliate of its new owner, Brookfield Asset Management. As such, in August, Westinghouse left bankruptcy protection after Brookfield Business partners acquired it under a reorganisation plan. In a July press release, the US DoE announced that almost USD 20 million had been awarded to nine domestic projects as part of a US Industry Opportunities for Advanced Nuclear Technology Development programme.

In February, Rosenergoatom, Rosatom's subsidiary responsible for domestic plant management, started commercial operation of its 1 000-MW unit located at Rostov, the latest of a series of nuclear reactors built in a short timeframe. Rosatom plans to apply the Rostov experience of serial construction of nuclear units to its foreign projects, including in Belarus, Bangladesh, Hungary and Turkey. A new VVER-1200 reactor, unit 1 of the Leningrad Phase II NPP in northwest Russia, attained minimum controlled power in spring and started commercial operation at the end of October.

Regarding the IAEA LEU Bank, the transit agreement with China entered into force in February 2018, and transport contracts with the authorised organisations from the Russian Federation and Kazakhstan were signed in September and November 2018, respectively.

Natural uranium production

In 2018, global uranium production fell by 11% compared with 2017, totalling 53 081 tonnes of uranium. The top three uranium-producing countries were Kazakhstan, Canada and Australia.

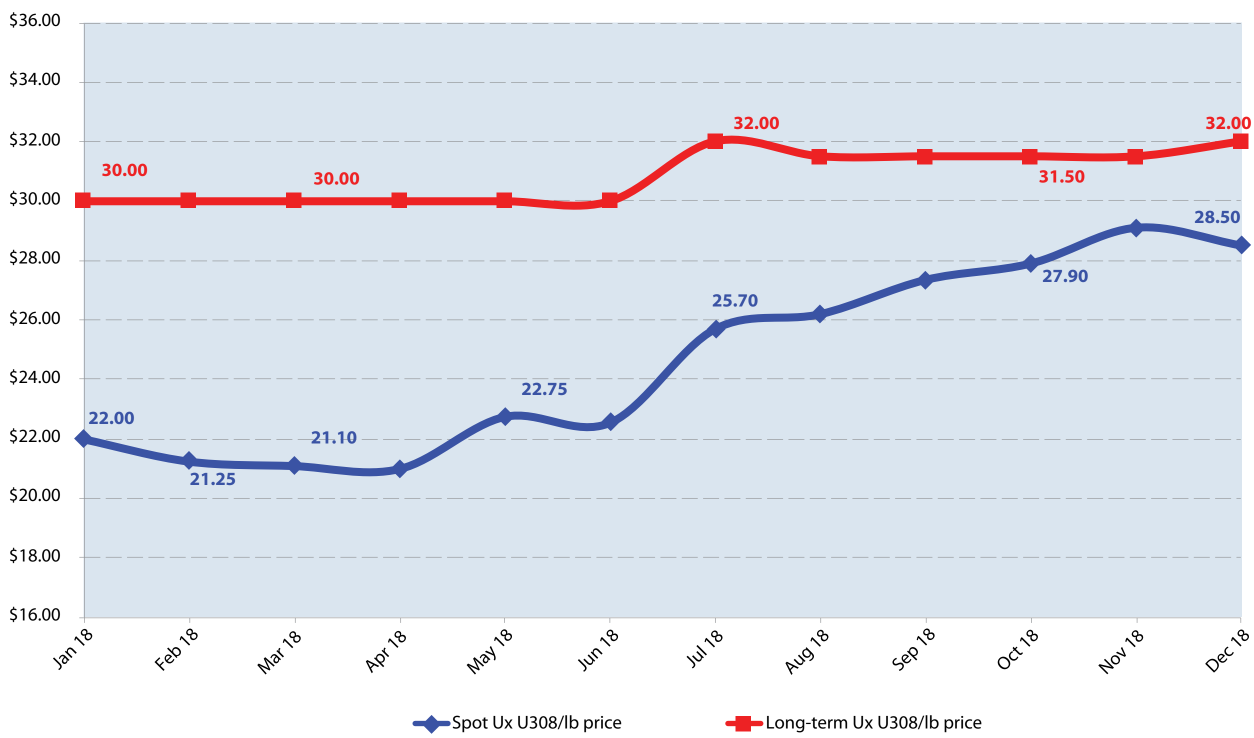
Kazakhstan remained the world's leading uranium producer in 2018, accounting for 41% of total worldwide uranium output. The country's uranium production accounted for 21 540 tU in 2018, a decrease of 8% on the 2017 output. Canada's production was estimated at around 7 000 in 2018, a significant decrease of 47% compared with the 2017 data. The drops in production output in both countries are in line with the announced policies of downscaling production in the current market situation. Australia's production increased by 9% from 2017, totalling 6 385 tU at the end of 2018.

Table 2. Natural uranium estimated production in 2018 (compared with 2017, in tonnes of uranium)

Region/country	Production 2018 (estimate)	Share in 2018 (%)	Production 2017 (final)	Share in 2017 (%)	Change 2018/2017 (%)
Kazakhstan	21 540	41	23 321	39	-8
Canada	7 001	13	13 116	22	-47
Australia	6 385	12	5 882	10	9
Namibia	5 539	10	4 224	7	31
Niger	2 923	6	3 449	6	-15
Russia	2 923	6	2 917	5	0
Uzbekistan	2 423	5	2 404	4	1
China	1 858	4	1 885	3	-1
Others	874	2	466	1	88
Ukraine	654	1	550	1	19
United States	615	1	940	2	-35
South Africa	346	1	308	1	12
Total	53 081	100	59 462	100	-11

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

Figure 1. Monthly spot and long-term U_3O_8/lb prices (in USD)



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The Ux spot price started the year at USD 23.75 per pound, unchanged from the end of 2017, but fell slightly at the end of January to USD 22 per pound. During the first quarter of 2018, the Ux spot price remained rather flat at USD 21 per pound. During the second quarter, the price rebounded, amounting to USD 22.55 per pound at the end of June. During the second half of the year, the price continued to grow, reaching

USD 27.35 at the end of September and USD 28.50 at the end of December.

The Ux long-term price began the year with a decrease, then settled at USD 30 per pound and remained flat through the end of June. Following news of additional production cuts, the term indicator increased by USD 2 at the end of July, to USD 32 per pound, but soon slipped back to USD 31.50 per pound in August, which was the level held until the end of November. The indicator ended the year at USD 32 per pound.

Secondary sources of supply

In 2018, 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, down-blended uranium, reprocessed uranium (RepU) and plutonium recovered from spent fuel, depleted uranium and uranium saved through underfeeding.

According to various industry reports, depleted uranium represents a significant source of uranium (WNA estimates the current world stock at about 1.2 million tonnes) that could add to the primary production by being re-enriched to the level of either natural uranium or LEU. It is estimated that on average 40 000 to 70 000 tonnes of depleted uranium will be added annually to the existing stocks until 2030, when the stockpile will represent more than 2 million tonnes. These depleted uranium stocks are either stored as UF_6 or, as is the case in France, Russia and the US, deconverted back to U308, a more stable and less toxic chemical form more suited for long-term storage. Depleted uranium could potentially be used as fuel in future generations of fast neutron reactors.

Due to the current global enrichment overcapacity, tails assays have been driven downward at enrichment facilities to underfeed the centrifuge plants and create a source of secondary supply that has grown significantly in the last few years, i.e. uranium saved through underfeeding. In its 2017 report[49], WNA estimated that global underfeeding and tails re-enrichment will continue to contribute an additional 3 500 to 7 000 tU of supply per year until 2025, gradually declining afterwards due to the expected increase in reactor demand and related enrichment services.

Uranium exploration and mine development projects

According to the 26th edition of OECD Nuclear Energy Agency and the IAEA's biennial joint publication, *Uranium 2018: Resources, Production and Demand*, also known as the 'Red Book'[50], the world's supply of uranium is more than adequate to meet projected requirements for the foreseeable future, regardless of the role that nuclear energy ultimately plays in meeting future electricity demand and global climate objectives. However, the report highlights that significant investment and technical expertise will be required to ensure these uranium resources can be brought into production in a timely manner, including from mines currently under care and maintenance.

According to press releases from January, Russia and Argentina signed a memorandum of understanding to promote cooperation in uranium exploration and mining, with a focus on in-situ recovery operations in Argentina, which hopes to become a leading uranium producer in the region. Russia opened its mining industry to foreign investment, as Russia-China Investment Fund for Regional Development, ARMZ Uranium Holding, and Priargunsky Industrial Mining and Chemical Union (PIMCU) signed an agreement for the construction and operation of PIMCU's Mine No. 6 in Krasnokamensk, Siberia, Russia, which hosts 38 000 tU (~99 million pounds U_3O_8) of reserves.

India is planning to increase its domestic uranium production tenfold by 2031-2032. In March, State Uranium Corp. of India Ltd. outlined expansion plans leading to self-sufficiency in uranium production. The plans provide for maintenance of sustained production from existing mines, capacity expansions at other mines, and new production centres.

Paladin Energy Ltd. announced in May that, following a rundown phase of up to 3 months during which plant circuits would be suspended and cleaned out, its Langer Heinrich uranium mine in Namibia would be placed into care and maintenance to preserve the mine's uranium resource and mitigate operating cash flow losses. On 6 December, Paladin announced that the mine had been undergoing optimisation studies. An updated Langer Heinrich preliminary feasibility study should be completed in 2019.

Cameco reported in July that it would keep its MacArthur River uranium mine shut for an indefinite period due to low uranium prices and an oversupplied spot market. The company estimated it would need to buy up to 4 million lbs of uranium in 2018 in order to honour its supply commitments.

According to official statements from Kazatomprom released in October, the company's production for 2018 would be 20% lower than originally planned for the year, amounting to around 27 000 mt U_3O_8. Production in 2019 and 2020 is set to be about the same as in 2018, still 20% lower than the levels originally planned.

In November 2018, Rio Tinto announced it had agreed to sell its majority stake in Rössing Uranium Limited to China National Uranium Corporation Limited.

(49) WNA, The Nuclear Fuel Report — Global Scenarios for Demand and Supply Availability 2017-2035.

(50) Published in December 2018 at https://www.oecd-nea.org/ndd/pubs/2018/7413-uranium-2018.pdf.

Conversion

Conversion plants are currently operating commercially in Canada, France, Russia and China. Current conversion capacity is considered to be more than sufficient to meet the global demand, albeit with a segmented market and production centred on a few suppliers.

In 2018, world nameplate primary conversion capacity was estimated at around 57 600 tU, with the actual conversion production assumed at 45 820 tU[51]. Part of the supply continued to be provided by secondary conversion sources. Secondary supply of equivalent conversion services includes UF6 material from commercial and government inventories, enricher underfeeding and depleted uranium tails recovery. Uranium and plutonium recycling add to this. Supply provided by primary and secondary conversion sources was able to meet the global demand for conversion services.

European and North American Ux spot conversion prices steadily increased from USD 6.25 per kgU and USD 6.00 per kgU, respectively, at the end of January to USD 13.75 per kgU and USD 13.50 at the end of December.

The Ux long-term conversion prices were stable in the first quarter of 2018 and amounted to USD 12.00 per kgU. They started to rise in April and continued to grow steadily until the end of October, when they accounted for USD 15.50 per kgU and stayed at the same level until end of year.

ORANO's new uranium conversion plant in southern France, or the Philippe Coste conversion plant, was officially opened on 10 September. The new facility has very low levels of chemical and energy consumption and is expected to reach a capacity of 15 000 metric tons of uranium per year by 2022. Conversion operations at the plant started at the end of September.

China's conversion capacity is expected to grow considerably through to 2025 and beyond, as the country plans to keep pace with domestic requirements and become a strong player in the global nuclear fuel market.

Table 3. Commercial UF_6 conversion facilities

Company	Nameplate capacity in 2018 (tU as UF_6)	Share of global capacity (%)
Atomenergoprom* (Russia)	18 000	31.3
Comurhex** II (France)	15 000	26.0
Cameco (Canada)	12 500	21.7
ConverDyn*** (United States)	7 000	12.2
CNNC (China)	5 000	8.7
IPEN (Brazil)	100	0.1
Total nameplate capacity	57 600	100

Because of rounding, totals may not add up.

Source: www.world-nuclear.org

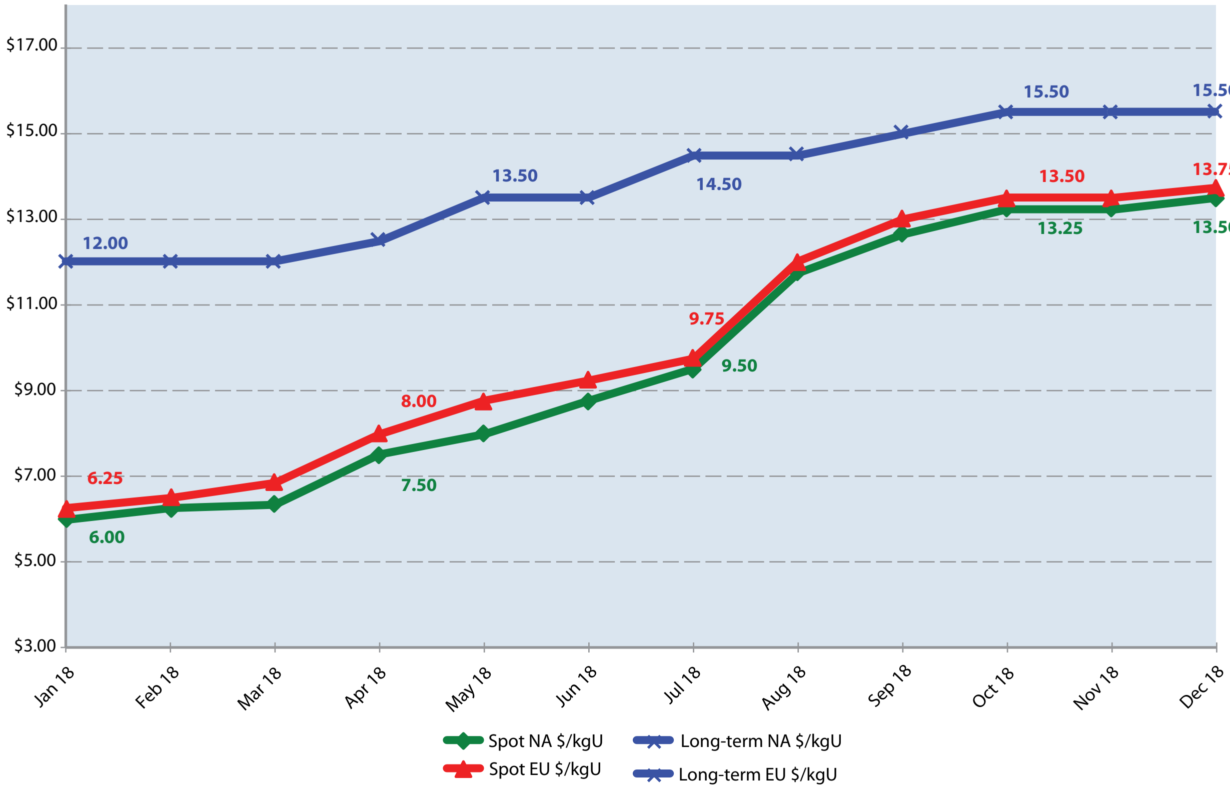
* Nameplate capacity 100% assumed

** Approximate capacity installed 10 500 tU

*** Activity suspended since end of 2017

(51) www.world-nuclear.org

Figure 2. Uranium conversion price trends (in USD)



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Enrichment

In 2018, the demand for enrichment services was evaluated at around 50 000 tSW. According to the WNA's latest estimates, world enrichment requirements are expected to rise between 2017 and 2030, albeit at a rate slower than indicated in the 2015 WNA Fuel report, reaching around 73 000 tSW by 2035. The increase is mainly driven by the new nuclear build prospects in Asian and Middle Eastern countries, particularly in China and India.

The current commercial enrichment nameplate capacity of approximately 60 000 tSW is considered to be sufficient to cover demand until 2020. Although projected capacities are sufficient to meet enrichment demand at least through 2025, primary suppliers may not be able to replace ageing equipment under current market conditions. Secondary SWU supply sources (inventories of previously-produced EUP, enriched uranium obtained from downblending HEU or SWU saved through use of MOX and ERU) will also be available to meet world enrichment requirements beyond this date.

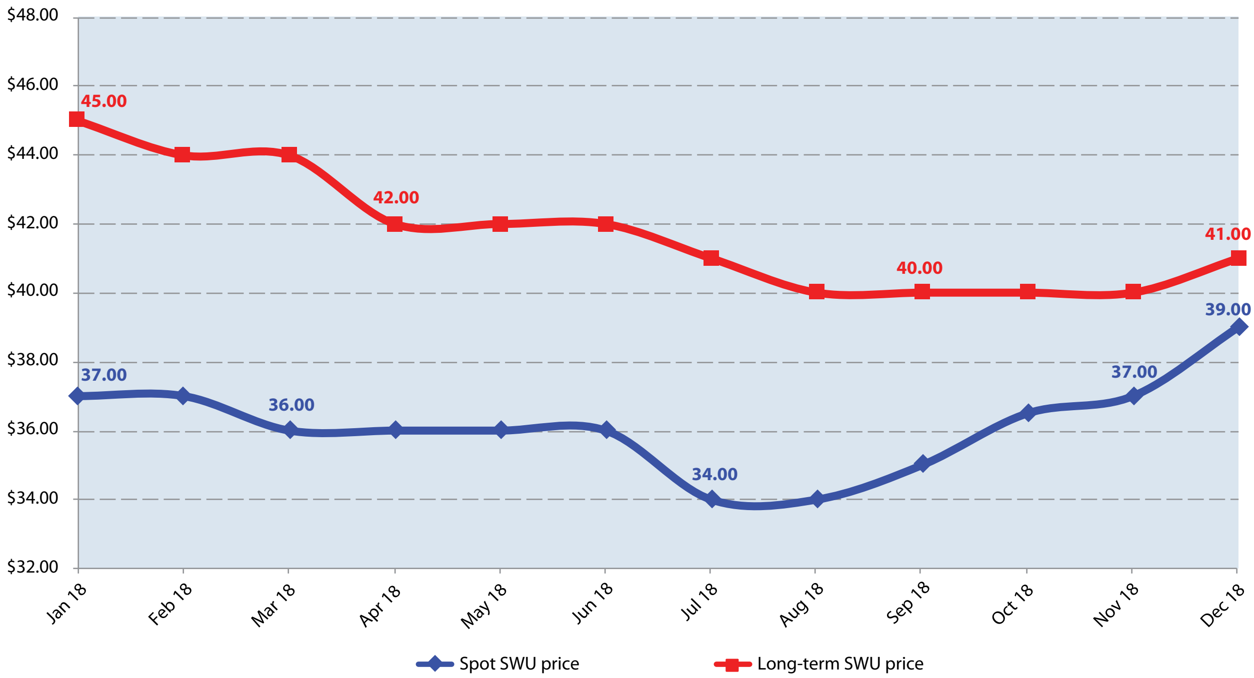
Large commercial enrichment plants are in operation in France, Germany, the Netherlands, the UK, the US and Russia, with smaller plants elsewhere. China is expanding its capacity, in an attempt to meet its growing domestic enrichment requirements while also pursuing export sales. With surplus capacity, some plants operate at low tails assays (underfeeding) to produce natural uranium for sale. Should the market demand recover in the medium term, the industry estimates that existing suppliers could rapidly expand their capabilities to cover any supply gap.

Table 4. Operating commercial uranium enrichment facilities, with approximate 2018 capacity

Company	Nameplate capacity (tSW)	Share of global capacity (%)
TVEL (Russia)	28 416	45.0
Urenco (UK/Germany/Netherlands/United States)	18 758	32.3
Orano (France)	7 500	12.7
CNNC (China)	5 210	9.8
Others* (CNEA, INB, JNFL)	188	0.3
World total	60 072	100

Because of rounding, totals may not add up.
Source: WNA, The Nuclear Fuel Report — Global Scenarios for Demand and Supply Availability 2017-2035. (*) CNEA, Argentina; INB, Brazil; JNFL, Japan.

Figure 3. Monthly spot and long-term SWU prices (in USD)



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In March, CNNC completed a large-scale demonstration project for a new generation of uranium enrichment centrifuges at the Hanzhong enrichment facility. Following another successful demonstration project conducted in November, the company's domestic uranium enrichment centrifuges received national approval for large-scale commercial use, marking an important step in the development of China's national nuclear industry.

At the end of August, Brazil's Indústrias Nucleares do Brasil (INB) reported that a seventh cascade of ultracentrifuges had been added to its Resende uranium enrichment plant. The government's current forecast is to expand to a total of ten ultracentrifuges by 2019, which would meet approximately 70% of Brazil's ANGRA 1 reactor's demand. The project provides for 30 additional ultracentrifuge towers to be installed by 2033, enabling INB to supply 100% of the enriched uranium requirements of the current ANGRA 1 & 2 units, plus the ANGRA 3 reactor, under construction, but any development depends heavily on future political context.

In June, Silex Systems Ltd. decided to abandon its acquisition of a majority stake in Global Laser Enrichment (GLE), a joint venture of General Electric, Hitachi and Cameco, on account of GLE's business case being too risky.

In 2018, the IAEA signed contracts with Kazatomprom and Orano Cycle for the purchase of LEU, destined to supply the IAEA LEU fuel Bank in Kazakhstan.

During 2018, the spot Ux SWU price experienced a steady decrease until the end of August, when it reached USD 34.00 per SWU. It rebounced in September, continuing its growth also in the fourth quarter, ending the year at the level of USD 39.00 per SWU in December.

The Ux long-term SWU showed a steady decrease during 2018. It began the year at USD 45.00 per SWU and slipped to USD 42.00 per SWU at the end of June. Additional declines were noted in July and August. As a result, the term stayed at the level of USD 40.00 per SWU between August and November and rebounced slightly to USD 41.00 per SWU in December.

Fabrication

The main fuel manufacturers are also reactor vendors, usually supplying the initial cores and early reloads for reactors of their own design. The largest fuel fabrication capacity can be found in the EU (Germany, Spain, France, Sweden and the United Kingdom), Russia and the United States.

Ukraine's Energoatom signed a nuclear fuel contract extension with Westinghouse Electric Co. for fuel deliveries to 7 of the country's 15 nuclear reactors between 2021 and 2025, thus expanding the scope of the existing contract between the two companies, set to expire in 2020. The fuel assemblies will be manufactured at Westinghouse's Vasteras, Sweden fuel facility on production lines that are solely dedicated to VVER-1000 reactors.

Except for the VVER fuel, the fuel fabrication market is very competitive. As a result, a trend of continuously improving fuel design has emerged, focusing on enhanced burnups and improved performance and safety.

In January, Lightbridge Corp. (US) and Framatome signed an agreement to set up a 50/50 joint venture called Enfission to develop, test and manufacture Lightbridge's advanced metallic fuel, expected to begin commercial sales in 2026. The joint venture's activities will encompass fuel for PWRs, BWRs, light water-cooled small- and medium-sized reactors and research reactors. Framatome, Global Nuclear Fuel (GNF), Westinghouse and Lightbridge are also working to develop accident-tolerant fuel (ATF), as this type of fuel could withstand loss of cooling in the reactor core for longer than the existing fuel designs, and could also enhance reactor performance. In February, the Southern Company loaded the first lead test assemblies for two GNF ATF designs into its Hatch NPP.

In May, ENUSA and Westinghouse Electric Company signed a framework cooperation agreement to collaborate in the development of Westinghouse's EnCore Accident Tolerant Fuel. The fuel incorporates concepts such as chrome-plated zirconium alloy sheaths, silicon carbide sheaths and uranium silicide (U_3Si_2) fuel pellets.

Also in May, Rosatom announced it was running tests on its prototype ATF, which might be marketable by the early 2020s, and could be used both in VVERs and in PWRs. According to Rosatom, TVEL's prototype fuel assemblies are already being tested at the Research Institute of Atomic Reactors in Dimitrovgrad.

Centrus Energy Corp. reported on 29 November that it had signed an agreement with X-energy LLC providing for transfer of expertise and resources to support the preliminary design of a facility able to produce X-energy's advanced nuclear fuel, or TRISO fuel. TRISO fuel could meet the requirements for various advanced nuclear reactor technologies being developed around the world.

In 2018, Toshiba Corp. sold its 14% stake in Global Nuclear Fuels (GNF) to Hitachi, whose stake in GNF increased to 40%, with General Electric holding the remaining 60%.

In April, Japan's Nuclear Regulation Authority (NRA) officially announced that Japanese uranium fuel fabricators must shut down their factories for 2 to 4 years in order to perform the safety engineering work required by the plant upgrade plans approved by the national regulator. Expected to start in 2019, the engineering work would focus on reinforcing structures and equipment to protect factories against earthquakes. Nuclear Fuel Industries Ltd. announced that its PWR fuel fabrication facility in the Osaka prefecture will close from September 2018 to July 2020.

Reprocessing and recycling

One of the most important features of nuclear energy is that used fuel can be reprocessed to recover fissile and fertile materials to provide fresh fuel for existing and future nuclear power plants. Several EU countries, China, India, Russia and Japan have opted for the closed fuel cycle (reprocessing and recycling used nuclear fuel), while many other countries continue to see used fuel as waste rather than a resource and opt for its direct disposal. In 2018, recovery of uranium and plutonium through reprocessing of spent fuel was carried out in France, the United Kingdom and Russia. The current commercial reprocessing capacity is around 5 000 tonnes per year for normal oxide fuels, but not all of it is operational.

Reprocessed uranium (as ERU fuel assemblies) and plutonium (in MOX fuel) still played a role in meeting the demand for nuclear fuel in 2018, as a replacement for fresh LEU in the supply mix of European, Russian and Japanese utilities. The latest available industry data indicate that by the end of 2018 there were 32 reactors, or about 7% of the world's operating fleet, licensed to use MOX fuel, including reactors in France, Germany, India, Japan and the Netherlands. To date, there are significant stockpiles of plutonium worldwide, and countries like Russia, Japan and China are considering additional fabrication capacity for MOX fuel. Due to the complex nature of the required upstream reprocessing of used nuclear fuel, the latest industry estimates indicate that, during 2017-2035, using MOX and ERU would result in savings of around 2 million SWU per year worldwide ([52]).

Framatome signed a protocol to develop strategic cooperation with CNNC in the fields of nuclear fuel design, engineering, and services. A memorandum of commercial agreement was also signed between Orano and CNNC for a project to build a commercial spent nuclear fuel treatment and recycling plant in China. Designed to have a capacity of 800 metric tons, the plant will be modelled after the Orano La Hague and Melox facilities.

In June, Orano signed a framework Support Services Agreement with Japan Nuclear Fuel Limited (JNFL) covering the Rokkasho Reprocessing Plant and the mixed-oxide (MOX) fabrication plant (J-MOX), currently under construction at the Rokkasho-Mura site in Northern Japan. Under the agreement, experts from Orano Melox and Orano Projets will perform a technical review by April 2019 of J-MOX key equipment, looking at maintainability, operation, and product quality. In addition, experts from Melox will share their experience of maintenance on some Melox equipment similar to the equipment planned for J-MOX.

In August, Urenco officially announced that its uranium Tails Management Facility (TMF) at Capenhurst had begun commissioning and was on track for operation start-up during 2019. Once complete, the TMF will enable Urenco to recycle about 5 000 tonnes of hydrogen fluoride a year for industrial use.

In December, Rosatom reported that the Mining and Chemical Combine in Krasnoyarsk Oblast, Russia, had started production of MOX fuel, intended to be used in the 800-MW Beloyarsk-4, a fast-neutron BN-800 reactor.

Reprocessing activity at the Thorp facility in the UK ceased in November 2018.

(52) WNA, The Nuclear Fuel Report — Global Scenarios for Demand and Supply Availability 2017-2035.

3. Nuclear fuels in the EU: supply and demand

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, and
- future contracted deliveries and inventories.

At the end of 2018, there were 126 commercial nuclear power reactors operating in the EU in 14 Member States and managed by 18 nuclear utilities. There were four reactors 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 Member States in 2017 was stable and amounted to 829.7 TWh, which accounted for 25.2% of total EU-28 production([53]).

Fuel loaded into reactors

In 2018, 2 225 tU of fresh fuel was loaded into commercial reactors in the EU-28. It was produced by using 15 912 tU of natural uranium and 565 tU of reprocessed uranium as feed, enriched with 12 075 tSW. The quantity of fresh fuel loaded was about the same level as in the previous year (i.e. 6.2 tU less than in 2017). In 2018, the fuel loaded into EU reactors had an average enrichment assay of 3.96%, 85% falling between 3.37% and

Bohunice NPP in Slovakia ©Slovenské elektrárne.jpg

4.55%. The average tails assay was 0.23%, more than 90% falling between 0.21% and 0.25%.

In 2018, MOX fuel was used in a number of reactors in France and the Netherlands. MOX fuel loaded into NPPs in the EU contained 8 080 kg Pu in 2018, a 24.5% decrease over the 10 696 kg Pu used in 2017. Use of MOX resulted in estimated savings of 726 tU and 510 tSW (see Annex 5).

The total amount of natural uranium included in fuel loaded into EU reactors in 2018, including natural uranium feed, reprocessed uranium and savings from MOX fuel, was 17 203 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 for about 8% of the EU's annual natural uranium requirements in 2018.

Table 5. Natural uranium equivalent included in fuel loaded by source in 2018

Source	Quantities (tU)	Share (%)
Uranium originating outside the EU	**15 912**	**92.4**
Indigenous sources ([1])	**1 291**	**7.6**
Total annual requirements	**17 203**	**100**

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

(53) Eurostat Energy Statistics, 2017.

Future reactor requirements (2019-2038)

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.

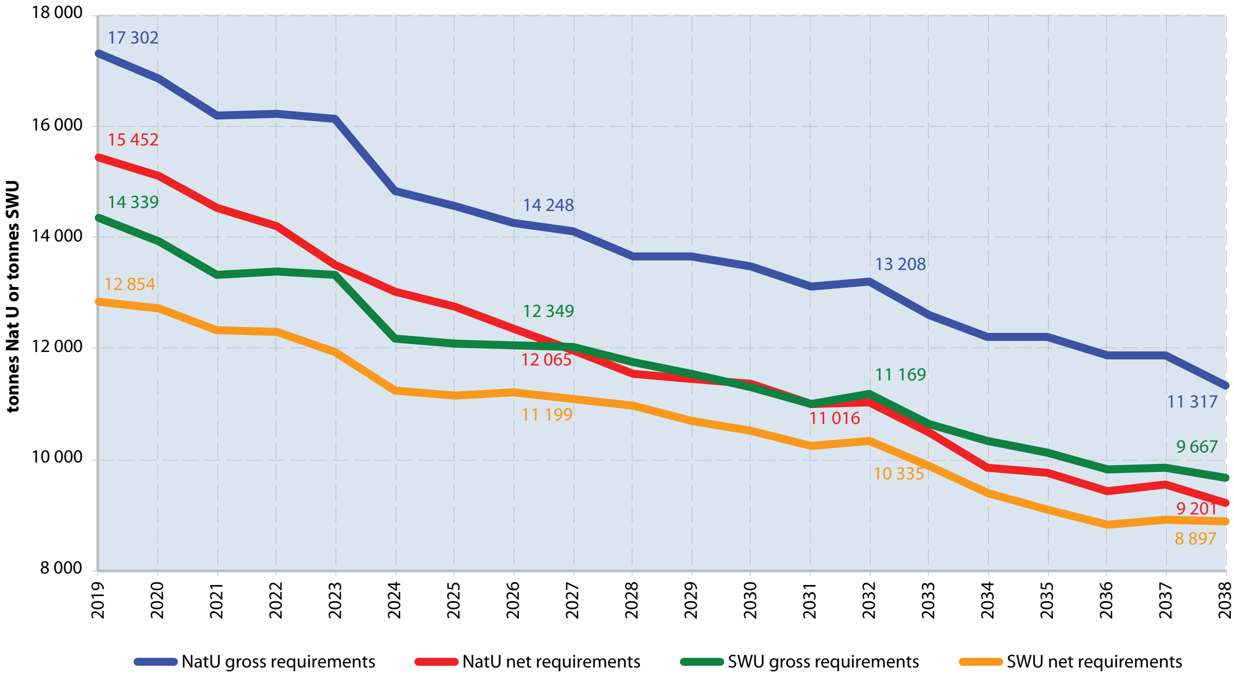
Natural uranium — average reactor requirements		
2019-2028	**15 415 tU/year (gross)**	**13 444 tU/year (net)**
2029-2038	**12 552 tU/year (gross)**	**10 309 tU/year (net)**

Enrichment services — average reactor requirements		
2019-2028	**12 839 tSW/year (gross)**	**11 776 tSW/year (net)**
2029-2038	**10 545 tSW/year (gross)**	**9 678 tSW/year (net)**

Estimates of future reactor requirements for uranium and separative work, based on data supplied by all EU utilities, are shown in Figure 4 (see Annex 1 for numerical values).

Compared to last year's annual survey, future aggregate requirements declared by the utilities have fallen slightly for the first 10-year period and decreased deeper for the second. For 2019-2028, forecasts of average gross requirements for natural uranium decreased by 4% (-688 tU), whereas they have fallen by 2% (-263 tSW) for separative work. For 2029-2038, the average gross demand for natural uranium decreased by 12% (-1 650 tU) and for enrichment services by 11% (11 864 tSW).

Figure 4. Reactor requirements for uranium and separative work in the EU-28 (in tonnes NatU or SWU)



Supply of natural uranium

Conclusion of contracts

In 2018, ESA processed a total of 102 natural uranium contracts and amendments to contracts, of which 61 were newly concluded. Of 51 new purchase/sale contracts, 24 involved EU utilities, and the remainder were signed by EU intermediaries or producers. Table 6 gives further details of the types of supply, terms and parties involved.

Table 6. Natural uranium contracts concluded by ESA (including feed contained in EUP purchases)

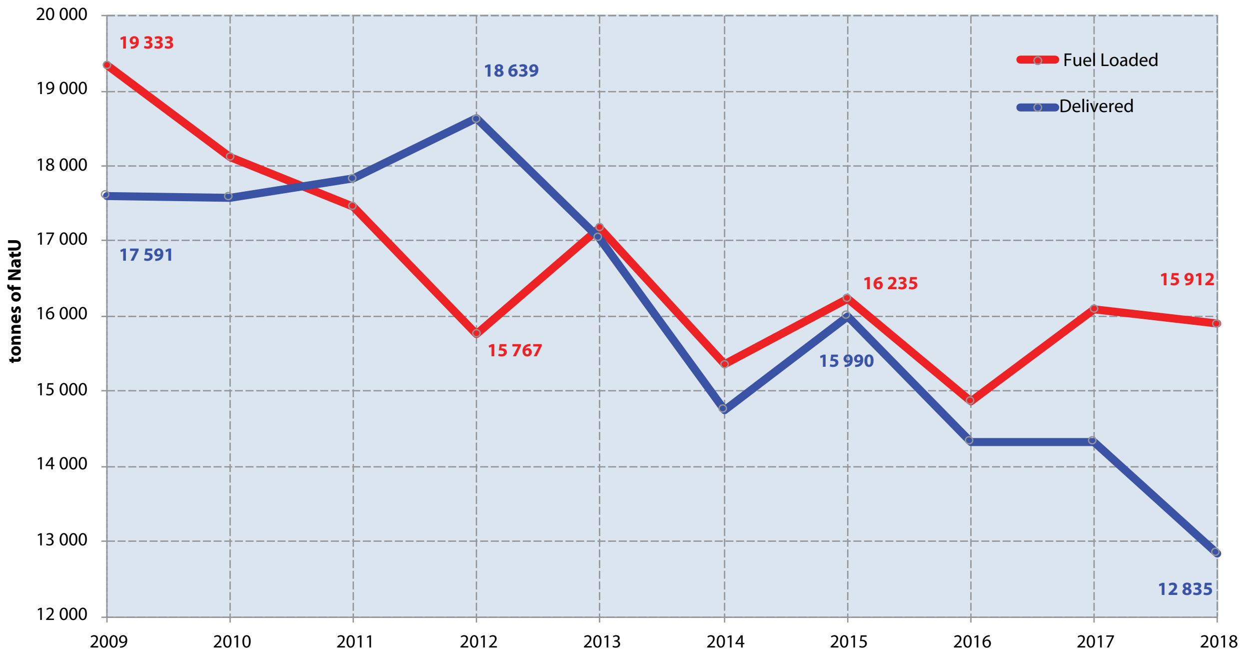
Type of contract	Number of contracts concluded in 2018	Number of contracts concluded in 2017
Purchase/sale by EU utilities/end users	24	25
— multiannual (1)	12	8
— spot (1)	12	17
Purchase/sale by EU intermediaries/producers	27	40
— multiannual	7	13
— spot	20	27
Exchanges and loans (2)	10	5
Amendments	41	53
TOTAL (3)	102	123

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

(2) This category includes exchanges of ownership and exchanges of U_3O_8 against UF_6. Exchanges of safeguard obligation codes and international exchanges of safeguard obligations are not included.

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

Figure 5. 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 2018, excluding research reactors. The natural uranium equivalent contained in enriched uranium purchases, when stated, is also taken into account.

In 2018, 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 140 deliveries under multiannual and spot contracts, which is 10% (-1 477 tU) less than in 2017. 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 12 200 tU (of which 11 435 tU with reported prices) or 95% of total deliveries, whereas the remaining 5% (635 tU) was purchased under spot contracts. On average, the quantity of natural uranium delivered was 91 tU per delivery under multiannual contracts and 106 tU per delivery under spot contracts.

Natural uranium contained in the fuel loaded into reactors in 2018 totalled 15 912 tU. For the last 5 consecutive years, EU utilities have been loading more material into reactors than buying material, which results in a steady decrease in inventory levels. Figure 5 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 1980-2018).

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 formulae based on uranium price and inflation indices.

ESA's price calculation method is based on currency conversion of the original contract prices, using the average annual exchange rates published by the European Central Bank, into EUR per kg uranium (kgU) in the chemical form U_3O_8. 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 uranium is priced in US dollars, fluctuations of the EUR/USD exchange rate influence the level of the price indices calculated. The annual average ECB EUR/USD rate in 2018 stood at 1.18, which was 5% higher 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 U_3O_8 price: the weighted average of U_3O_8 prices paid by EU utilities for uranium delivered under spot contracts in 2018 was calculated as:	
EUR 44.34 kgU contained in U_3O_8	**20% down from EUR 55.16/kgU in 2017**
USD 20.14/ lb U_3O_8	**16% down from USD 23.97/lb U_3O_8 in 2017**

2. ESA multiannual U_3O_8 price: the weighted average of U_3O_8 prices paid by EU utilities for uranium delivered under multiannual contracts in 2018 was calculated as:	
EUR 73.74 kgU contained in U_3O_8	**8% down from EUR 80.55/kgU in 2017**
USD 33.50/ lb U_3O_8	**4% down from USD35.00/lb U_3O_8 in 2017**

3. ESA 'MAC-3' multiannual U_3O_8 price: the weighted average of U_3O_8 prices paid by EU utilities, only for multiannual contracts which were concluded or for which the pricing method was amended in the past 3 years and under which deliveries were made in 2018, was calculated as:	
EUR 74.19 kgU contained in U_3O_8	**8% down from EUR 80.50/kgU in 2017**
USD 33.70/ lb U_3O_8	**4% down from USD 34.98/lb U_3O_8 in 2017**

The ESA U_3O_8 spot price reflects the latest developments on the uranium market, as it is calculated from contracts providing either for a single delivery or for a number of deliveries over a maximum of 12 months. In 2018, the ESA U_3O_8 spot price was EUR 44.34/kgU (or USD 20.14/lb U_3O_8). Prices fell within the range of EUR 41.73 to EUR 46.30/kgU (USD 18.96 to USD 21.03/lb U_3O_8).

The ESA multiannual U_3O_8 price was EUR 73.74/kgU U_3O_8 (USD 33.50/lb U_3O_8). The multiannual prices paid varied widely, with approximately 65% (assuming a normal distribution) falling within the range of EUR 49.43 to EUR 103.14/kgU (USD 34.65 to USD 46.85/lb U_3O_8). Usually, multiannual prices trade at a premium to spot prices, as buyers are willing to pay a risk premium to lock in future prices. However, the ESA multiannual U_3O_8 price is not forward-looking. It is based on historical prices contracted under multiannual contracts, which are either fixed or calculated on the basis of formulae indexing mainly uranium spot prices. Spot prices are the most widely indexed prices in multiannual contracts. The ESA multiannual U_3O_8 price paid for uranium originating in the Commonwealth of Independent States (CIS - Russia, Kazakhstan and Uzbekistan) was 22% lower than the price for uranium of non-CIS origin.

The ESA MAC-3 multiannual U_3O_8 price was EUR 74.19/kgU U_3O_8 (USD 33.70/lb U_3O_8). The data were spread across a wide range, with approximately 70% of prices reported as falling between EUR 45.01 and EUR 83.07/kgU (USD 20.44 to USD 37.74/lb U_3O_8). The ESA MAC-3 index takes into account only multiannual contracts signed recently (2016-2018) or older multiannual contracts for which the uranium pricing method was amended during the same period, thus incorporating current market conditions and providing insights into the future of the nuclear market. The ESA MAC-3 multiannual U_3O_8 price paid for uranium originating in CIS countries was 33% lower than the price for uranium of non-CIS origin.

Figures 6a and 6b show the ESA average prices for natural uranium since 2009. The corresponding data are presented in Annex 3.

Figure 6a. Average prices for natural uranium delivered under spot and multiannual contracts, 2009-2018 (EUR/kgU)

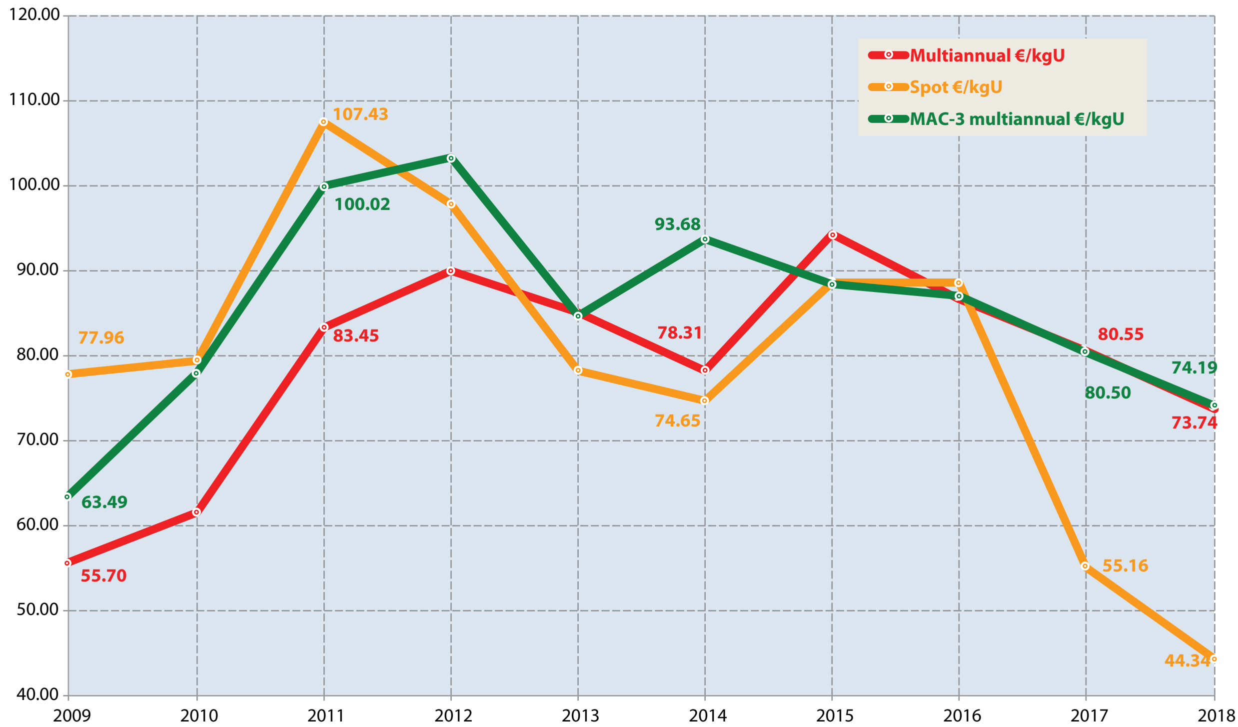
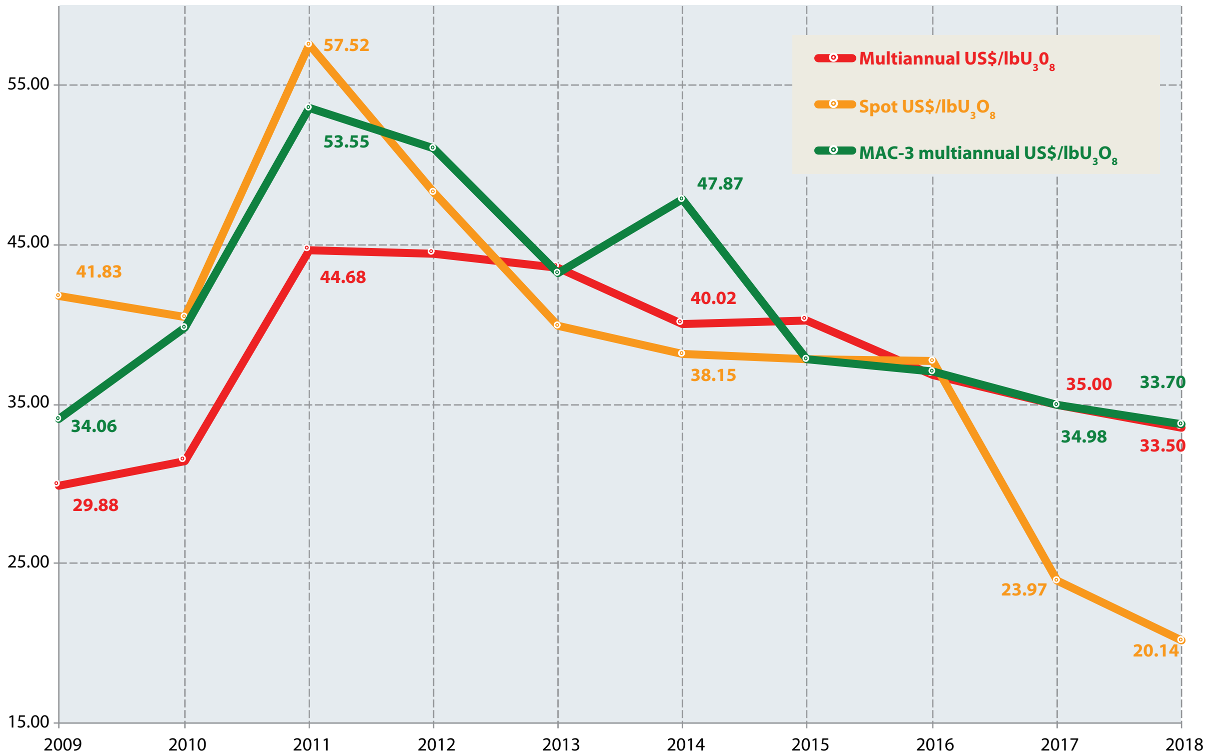


Figure 6b. Average prices for natural uranium delivered under spot and multiannual contracts, 2009-2018 (USD/lb U_3O_8)



Origins

In 2018, 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 2017, although there have been some changes in market share.

Table 7. Origins of uranium delivered to EU utilities in 2018 (tU)

Origin	Quantity	Share (%)	Change in quantities 2018/2017 (%)
Canada	3 630	28.3	-11.4
Niger	2 067	16.1	-3.9
Australia	1 909	14.9	-8.7
Russia	1 759	13.7	-19.8
Kazakhstan	1 754	13.7	-15.0
Namibia	1 046	8.1	13.4
Uzbekistan	166	1.3	-52.5
Re-enriched tails	161	1.3	-6.0
South Africa	118	0.9	–
United States	110	0.9	-42.9
Other	80	0.6	0.0
Ukraine	19	0.2	–
EU	18	0.1	–
Total	**12 835**	**100.0**	**-10.3**

Because of rounding, totals may not add up.

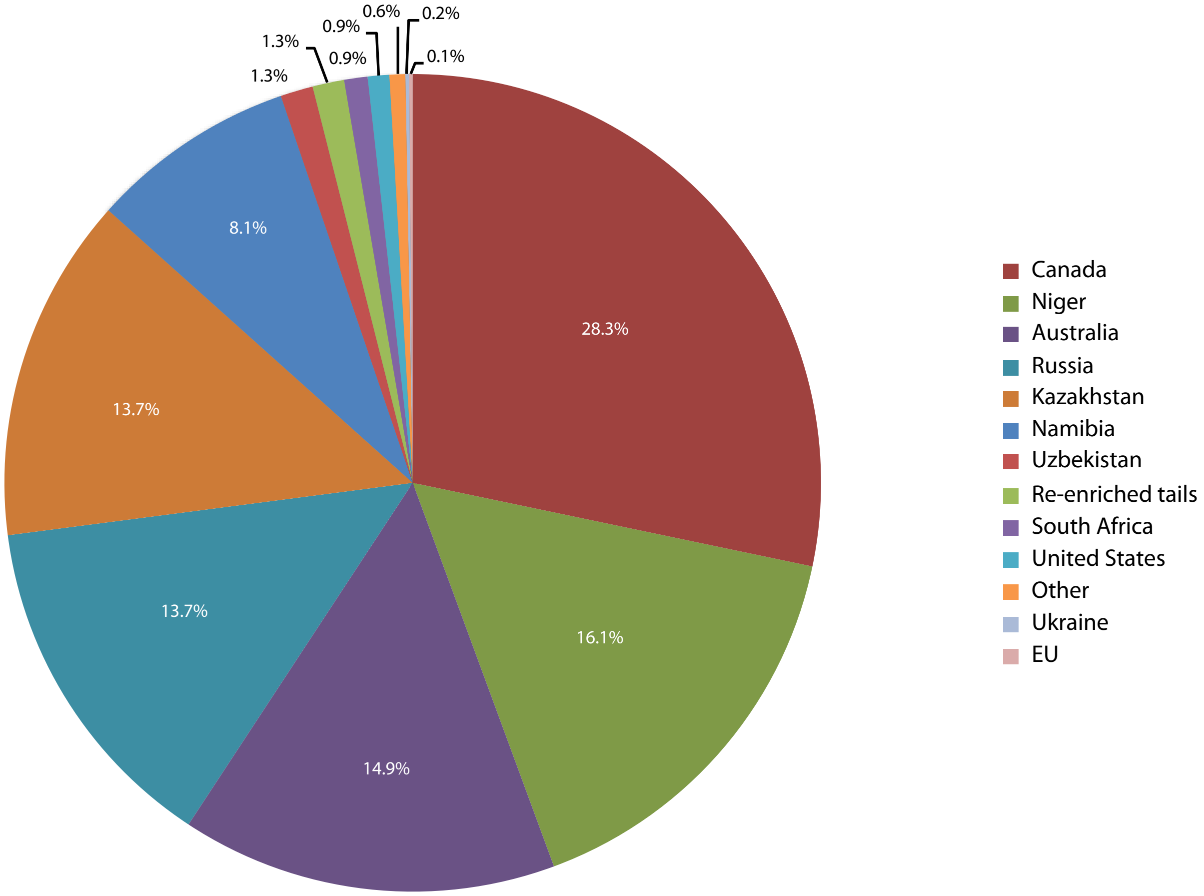
([1]) material saved through underfeeding, mixed origin and unknown

Canada and Niger were the top two countries delivering natural uranium to the EU in 2018, providing 44.4% of the total. Of this, uranium originating in Canada accounted for 28.3% of total deliveries, with that originating in Niger representing 16.1%. In third place, uranium mined in Australia amounted to 14.9% of the total. Russia (including purchases of natural uranium contained in EUP) and Kazakhstan accounted both for 13.7%. The five big producing countries together with Namibia, which was sixth, provided almost 95% of all natural uranium supplied to the EU.

Natural uranium produced in CIS countries accounted for 3 858 tU, or 30.1% of all natural uranium delivered to EU utilities, a 19% decrease from the year before.

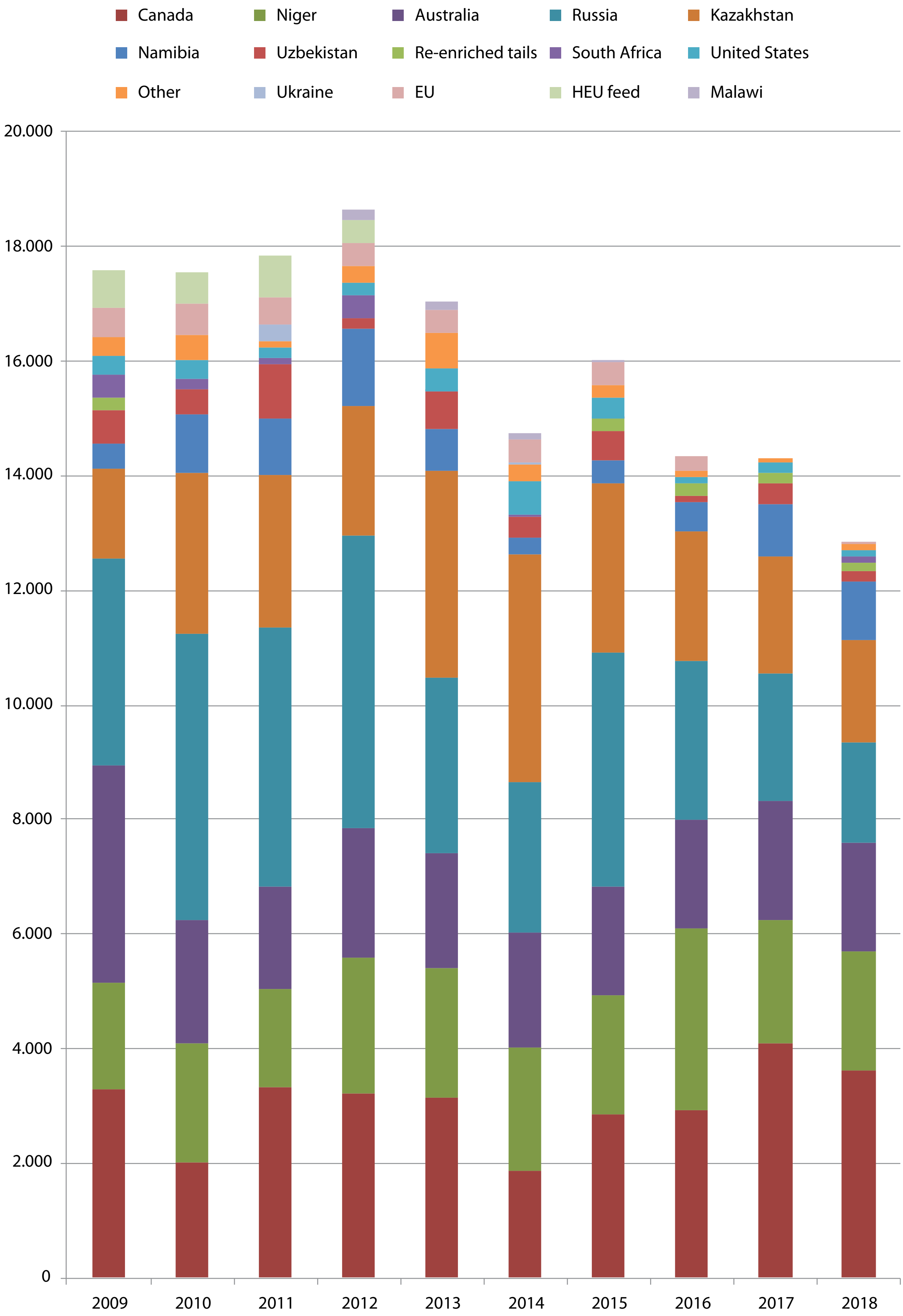
Deliveries of uranium from Africa increased by 5.1% to 3 231 tU, compared to 3 074 tU in 2017. Uranium mined in Africa originated in three countries, Niger, Namibia and South Africa, with Niger representing 64% of African-origin deliveries in 2018.

Figure 7. Origins of uranium delivered to EU utilities in 2018 (% share)



Because of rounding, totals may not add up.

Figure 8. Purchases of natural uranium by EU utilities, by origin, 2009-2018 (tU)



Conversion services

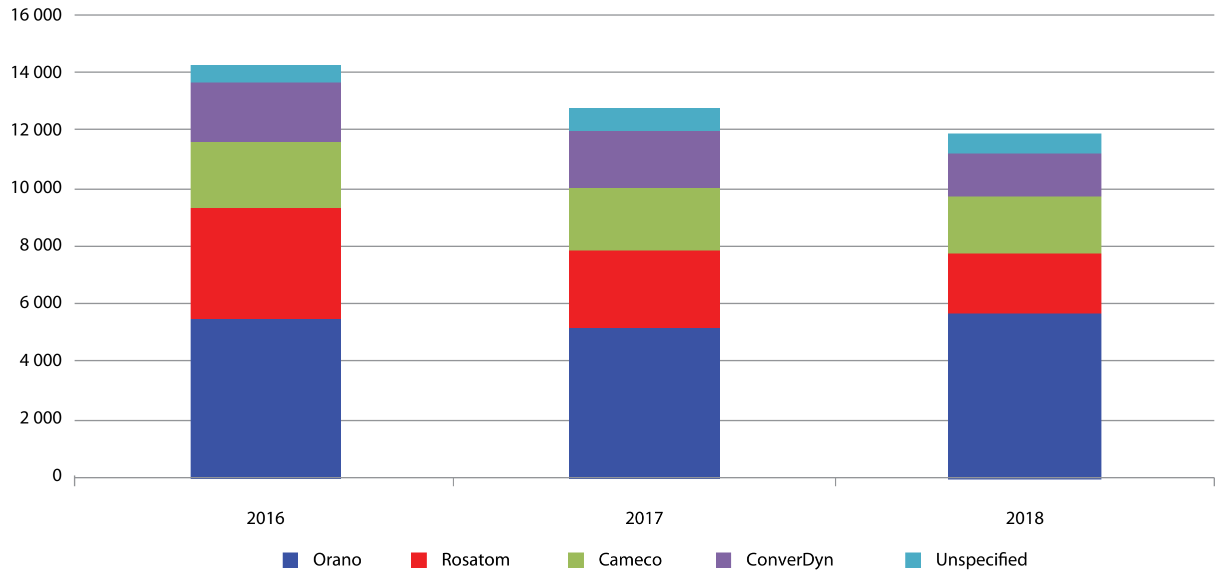
During 2018, EU utilities, producers and intermediaries notified to ESA 10 new contracts on provision of conversion services and 3 amendments to already notified conversion contracts.

In 2018, 8 605 tU were converted under separate conversion contracts, which accounted for 73% of all conversion service deliveries to EU utilities. The remaining 27%, or 3 263 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, 48% of EU requirements were provided by Orano / Comurhex, followed by Rosatom (17%), Cameco (17%) and ConverDyn (13%).

Table 8. Provision of conversion services to EU utilities

Converter	Quantity in 2018 (tU)	Share in 2018 (%)	Quantity in 2017 (tU)	Share in 2017 (%)	Change in quantities 2018/2017 (%)
Orano (EU)	**5 685**	**48**	**5 166**	**40**	**10**
Rosatom (Russia)	**2 017**	**17**	**2 668**	**21**	**-24**
Cameco (Canada)	**1 969**	**17**	**2 149**	**17**	**-8**
ConverDyn (US)	**1 562**	**13**	**2 010**	**16**	**-22**
Unspecified	**636**	**5**	**823**	**6**	**-23**
Total	**11 869**	**100**	**12 816**	**100**	**-7**

Figure 9. Supply of conversion services to EU utilities by provider, 2016-2018 (tU)



Special fissile materials

Conclusion of contracts

Table 9 shows the aggregate number of contracts, notifications and amendments (54) relating to special fissile materials (enrichment services, enriched uranium and plutonium) handled in 2017 and 2018 in accordance with ESA's procedures.

Deliveries of low-enriched uranium

In 2018, the enrichment services (separative work) provided to EU utilities totalled 10 899 tSW, delivered in 1 763 tonnes of low-enriched uranium (tLEU), which contained the equivalent of 13 580 tonnes of natural uranium feed. In 2018, enrichment service deliveries to EU utilities were about the same level compared to 2017, with NPP operators opting for an average enrichment assay of 4.10% and an average tails assay of 0.22%.

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

Table 9. Special fissile material contracts concluded by or notified to ESA

Type of contract	Number of contracts concluded/notifications acknowledged in 2018	Number of contracts concluded/notifications acknowledged in 2017
A. Special fissile materials		
New contracts	29	31
Purchase (by an EU utility/end user)	5	8
Sale (by an EU utility/end user)	3	3
Purchase/sale (between two EU utilities/end users)	7	4
Purchase/sale (intermediaries/producers)	8	12
Exchanges	6	4
Loans	0	0
Contract amendments	27	29
TOTAL (1)	56	60
B. Enrichment notifications (2)		
New notifications	15	11
Notifications of amendments	18	23
TOTAL	33	34

(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 10. Providers of enrichment services to EU utilities

Provider of service	Quantities in 2018 (tSW)	Share in 2018 (%)	Quantities in 2017 (tSW)	Share in 2017 (%)	Change in quantities 2018/2017 (%)
Orano/GBII and Urenco (EU)	7 151	66	7 691	71	-7
Tenex/TVEL (Russia)	3 462	32	2 524	23	37
Russian blended (1)	286	3	447	4	-36
Centrus (formerly USEC) (US)	0	-	200	2	-
TOTAL (2)	10 899	100	10 862	100	-

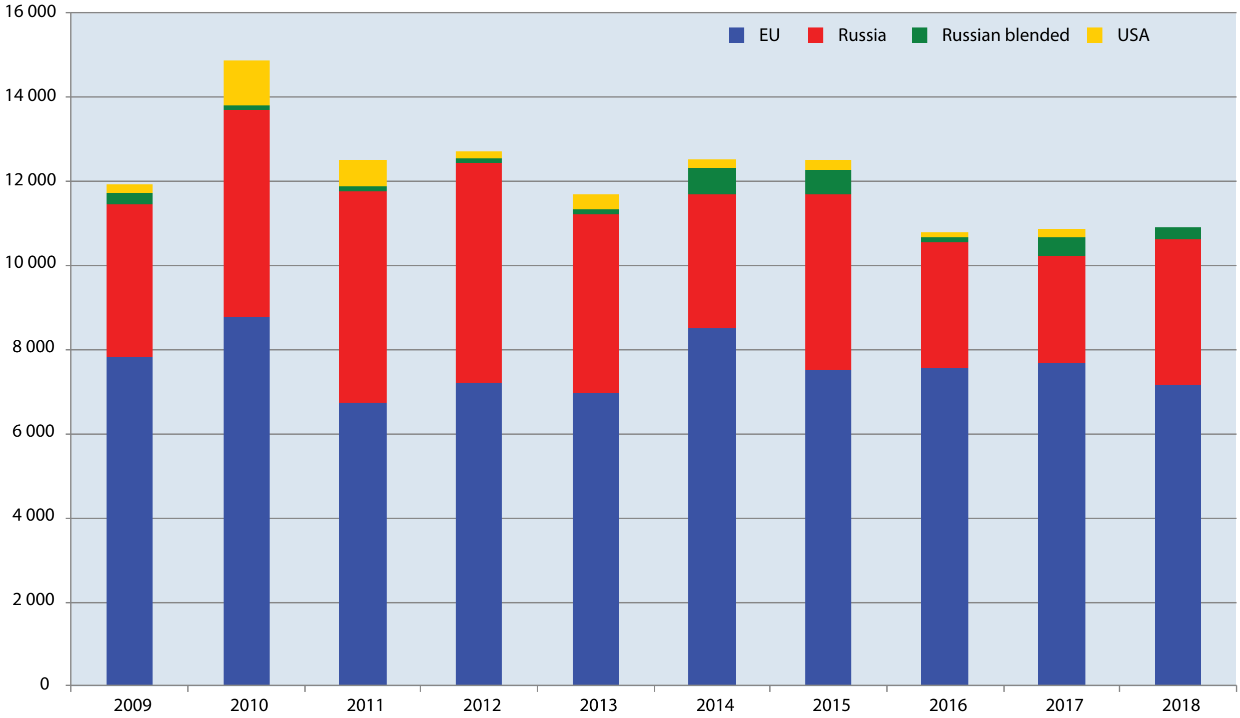
(1) Including enriched reprocessed uranium.

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

As regards the providers of enrichment services, 66% of EU requirements were met by the two European enrichers (Orano-GBII and Urenco), totalling 7 151 tSW, a decrease of 7 percentage points in year-on-year comparison.

Deliveries of separative work from Russia (Tenex and TVEL) to EU utilities under purchasing contracts totalled 3 462 tSW, which accounts for 32% of total deliveries, a 37% increase from 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. There were no enrichment services provided by Centrus.

Figure 10. Supply of enrichment to EU utilities by provider, 2009-2018 (tSW)



Plutonium and MOX fuel

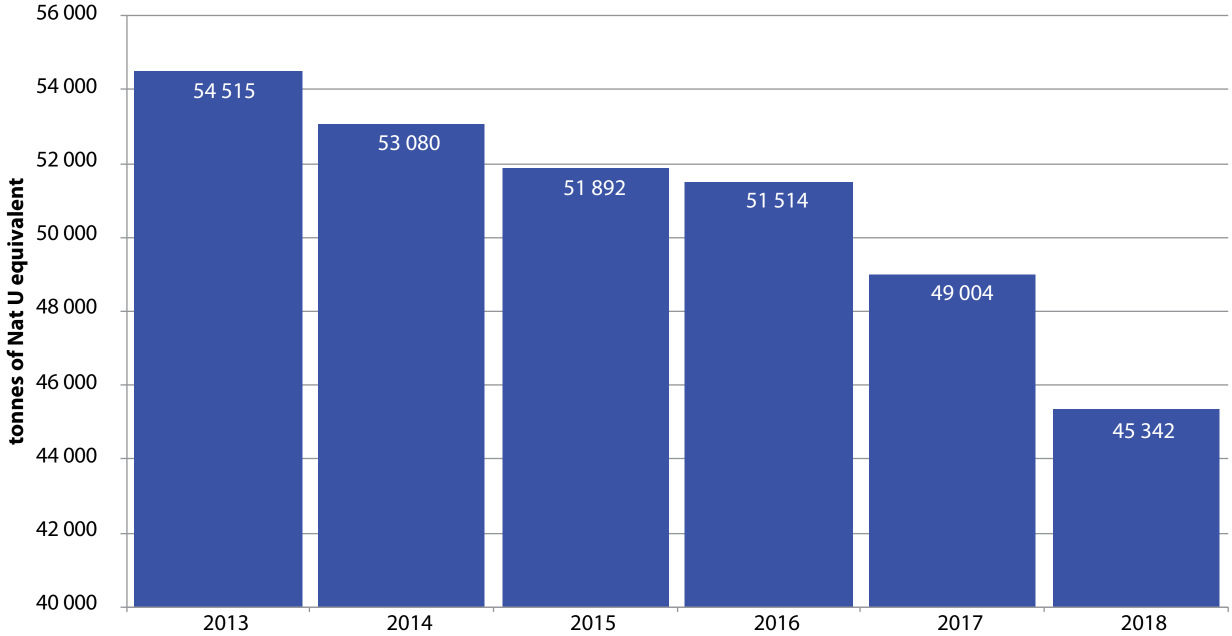
MOX fuel is produced by mixing uranium and plutonium recovered from spent fuel. Use of MOX fuel has an impact on reactor performance and safety requirements. Reactors have to be adapted for this kind of fuel and must obtain a special licence before using it. MOX fuel behaves similarly (though not identically) 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. It is widely recognised that reprocessing spent fuel and recycling recovered plutonium together with uranium in MOX fuel increase the availability of nuclear material, replace enrichment services, and contribute to the security of supply. The quantity of plutonium contained in the MOX fuel loaded into NPPs in the EU was 8 080 kg in 2018, a 24% decrease over the 10 696 kg used in 2017.

Borssele nuclear power plant in The Netherlands ©EPZ

Inventories

At the end of 2018, the natural uranium equivalent in inventories owned by EU utilities totalled 45 342 tU, a decrease of 7.5% from the end of 2017 and a decrease of 17% compared to the level at the end of 2013. 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 11. Total natural uranium equivalent inventories owned by EU utilities at the end of the year, 2013-2018 (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 11 shows the contractual coverage rate for natural uranium and SWUs, and figure 12 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 2019-2028 are estimated at approximately 13 444 tU and 11 776 tSW per year (see table in Annex 1). ESA assumes the same quantity of requirements for conversion services as for natural uranium. A distinction is drawn between demand for conversion services covered under separate conversion contracts and other contracts, which include deliveries of natural UF_6, EUP or bundled contracts for fuel assemblies.

Quantitative analysis shows that EU utilities are well covered until 2021, in terms of both natural uranium and enrichment services, under existing contracts. The respective coverage rates oscillate between 90% and 100%.

For natural uranium, supply is well secured from 2019 to 2022, with a contractual coverage rate of 88% in 2019 and staying high between 2020 and 2022. In the long term, the uranium coverage rate drops below 70% after 2022 and ends at 43% in 2027.

Enrichment service supply is well secured until 2022, with a contractual coverage rate of over 100%. It will stand between 72% and 86% until 2027.

In general, EU utilities' reactor requirements for both natural uranium and enrichment services are sufficiently covered in the short and medium term.

Quantitative analysis of conversion services shows that EU utilities' net reactor requirements are well covered under existing contracts with conversion services coverage rate between 94% and 119% until 2025. Supply is well secured until 2027, with a contractual coverage rate accounting for more than 60%.

Figure 12. Coverage rate for natural uranium and enrichment services, 2019-2027 (%)

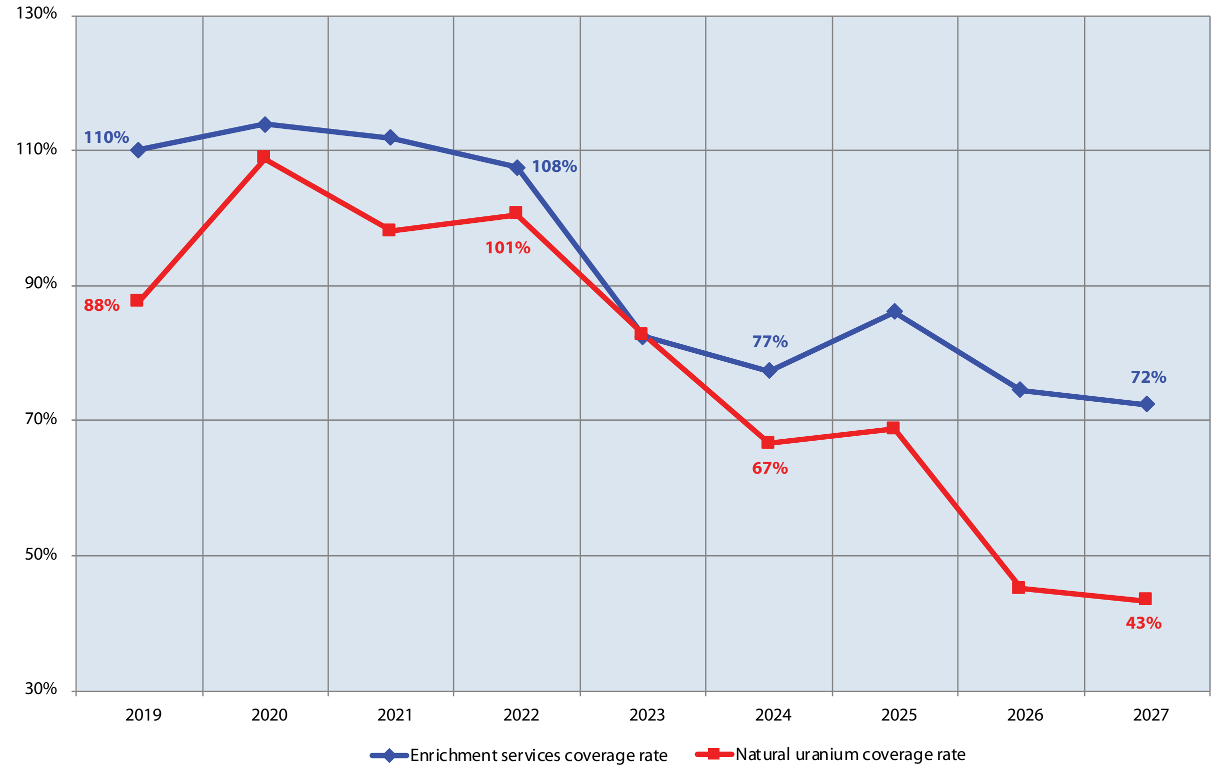
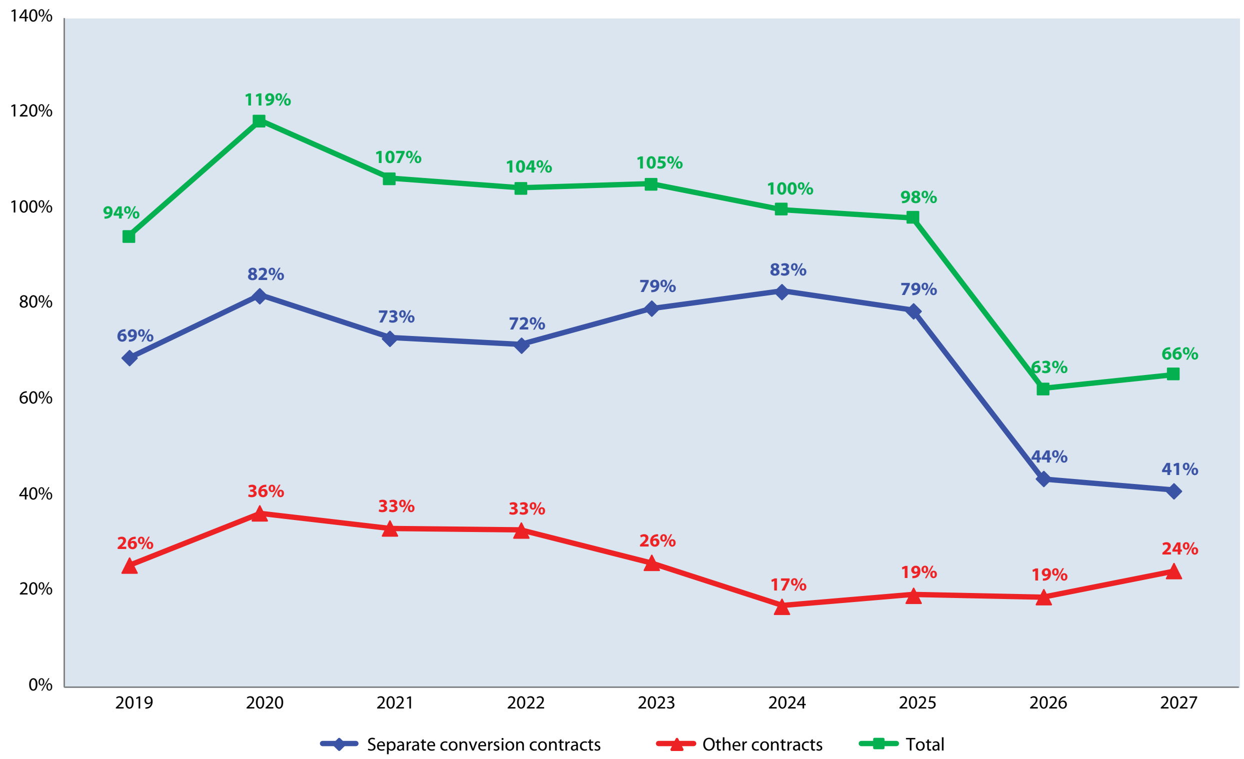


Figure 13. Coverage rate for conversion services, 2019-2027 (%)



ESA findings, recommendations and diversification policy

In accordance with its statutory mission, ESA has continued to monitor the nuclear market to identify market trends likely to affect the security of the EU's supply of nuclear materials and services. In line with the EU nuclear common supply policy, the Agency has exercised its exclusive right to conclude (sign) contracts and compiled comprehensive statistical reports on trends in the nuclear market. 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 recommends that utilities cover most of their current and future requirements under multiannual contracts from diverse sources of supply. In line with this recommendation, deliveries of natural uranium to the EU under multiannual contracts accounted for 96% of total deliveries in 2018. As for mining origin, the relative shares of individual producer countries changed in comparison with the previous year, with Canada, Niger, Australia, Russia, Kazakhstan and Namibia together providing 95.7% of the natural uranium delivered to the EU. In 2018, deliveries of uranium from Africa increased by 5.1%. In contrast, deliveries of uranium from all other regions decreased. The biggest drop was in figures for deliveries from the CIS (-19.2%) followed by deliveries from North America which decreased by 12.9% and Australia 8.7%. Overall, the deliveries of natural uranium to EU utilities are well diversified, but there are a number of utilities buying their natural uranium from only one supplier.

On the diversification of sources of supply of enriched uranium to EU utilities, 66% 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 (32%) and through downblending Russian highly enriched uranium (2%). Of the 32% of SWUs of Russian origin, contracts 'grandfathered' under Article 105 of the Euratom Treaty accounted for less than 4% of total deliveries.

In 2018, total deliveries of enrichment services were at about the same level as compared to 2017. The two European enrichers decreased their relative share in the EU market by 5 percentage points and Russian providers increased it by 7.

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 1% (161 tU) of the total feed material deliveries. MOX fuel loaded into NPPs in the EU contained 8 080 kg Pu in 2018 (a 24.5% decrease compared with 2017), resulting in estimated savings of 726 tU and 510 tSW.

ESA also recommends that EU utilities maintain adequate strategic inventories and use market opportunities to increase their stocks, depending on their individual circumstances. The aggregate stock level at the end of 2018 totalled 45 342 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.

On the supply side, 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 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.

Following an analysis of the information gathered from EU utilities in the annual survey at the end of 2018, 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.

4. Security of supply

Introduction

2018 was another year of gradual changes from previously established trends. Worldwide, nine new reactors started operation while three were shut down. Asia remains a growth region with China and India, whereas new build in Europe suffered further delays and setbacks. Reactor restarts in Japan have made some progress, although only nine reactors have so far returned to operation. The short-term outlook for nuclear in the United States did not improve, but small modular reactors (SMRs) could change the situation in the medium and longer term. Many countries in the world are planning to build their first nuclear power plants, but such projects usually take longer than initially expected. In the EU, France has presented more concrete plans on how to reduce the share of nuclear in its energy mix by 2035.

In 2018, the uranium market finally saw some concrete steps towards balancing supply and demand, with production cuts in Canada and Kazakhstan. On the other hand, some new mining projects have continued to advance, albeit slowly.

For countries and companies committed to nuclear energy, long-term security of supply remains of the utmost importance, regardless of market conditions. New reactors built today are generally expected to operate for 60 years, and perhaps up to 80 years, during which time business conditions and commodity prices will certainly fluctuate while the fuel needs will be constant.

Security of supply and ESA's diversification policy

For NPP operators, the main issue after nuclear safety is to ensure the continuous availability of fuel and the prevention of supply disruptions. Since nuclear energy still provides over one quarter of the EU's electricity, and in France, Hungary and Slovakia more than 50%, securing its supply is very important. Diversification is a key pillar of security of supply, for nuclear as well as for other energy sources.

ESA continues to monitor the market and provides analysis, with the aim of ensuring that EU utilities have diverse supply sources and do not become over-dependent on any single external source, as this could jeopardise the security of supply in the medium and long term. In addition to the open-source information, specialised media and data received while exercising its right to sign contracts, ESA maintains regular contacts with EU utilities and other fuel market participants. One key goal for the long-term security of supply is to maintain the viability of the EU industry at every stage of the fuel cycle.

In addition to the overall EU dependence level, it is important to note that some individual EU utilities remain 100% dependent on one external supplier. In such cases, the overall risk for a stable electricity supply needs to be evaluated, taking into account a number of factors: the share of nuclear in the energy mix of the Member State in which the utility is located, possible reserve capacities, the Member State's potential electricity exports to neighbouring Member States, and its capacity to import electricity in case of need.

In its market-monitoring role, ESA is responsible for the early identification of market trends likely to affect the medium- and long-term security of supply of nuclear materials and services in the EU, both at aggregate EU level and for individual utilities.

Flamanville NPP in France ©Alexis Morin

ESA may exercise its powers under Chapter 6 of the Treaty if:

- the situation in the market suddenly deteriorates and requires a quick reaction (in particular, if external dependence increases significantly in a short period of time or if imports are affected by the political situation or risk distorting competition within the EU internal market);
- a user fails to diversify its supply sources or to implement remedial measures.

Supply side — assessment of the global situation

Following production cuts in the US, Canada and Kazakhstan, and uncertainty over possible import restrictions in the US, common uranium spot price indicators increased during 2018. It remains to be seen whether this turnaround is durable, but many industry observers seem to believe that the low point of the price cycle is now behind. Still, many mines are operating at very thin margins or even at a loss, and the current price level does not encourage new exploration or mine development.

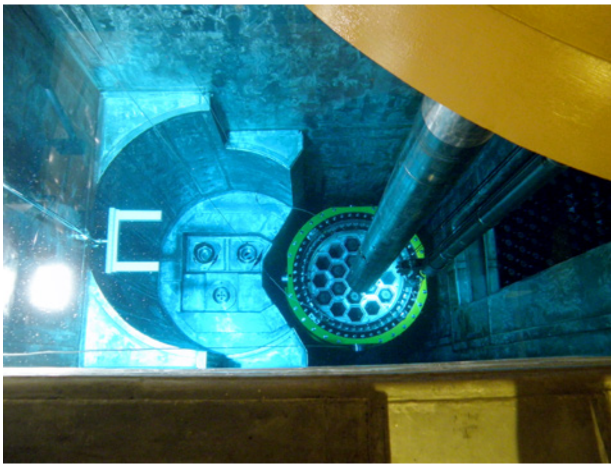
Although primary production does not cover worldwide reactor requirements, there is still over-supply on the market because of secondary sources (HEU down-blending, RepU and plutonium use in MOX fuel, inventory draw-down, tails re-enrichment), and more recently through underfeeding by enrichers who are trying to optimise the use of their facilities in the face of very low SWU prices.

At some stage, global uranium production will need to increase to meet demand from Asia and other emerging nuclear countries, and the industry is expected to be able to meet this challenge.

For the time being, plentiful inventories of uranium in the EU, Japan and China provide a buffer against an increase in prices similar to what occurred in 2005-2007.

All front-end fuel cycle services — conversion, enrichment and fuel fabrication — continue to suffer from world-wide over-capacity and low prices. As there are only a few players in each of these segments, all of them are needed to ensure long-term security of supply and a minimum of competition.

ESA has for years highlighted the importance of conversion as the smallest, but critical, step in the fuel cycle. In 2018, Orano opened its new conversion facility Philippe Coste at the Tricastin site in southern France. This greatly enhances security of supply for conversion services in the EU market and also for the global market. In addition, since Europe also has several enrichment facilities, this reduces the need for transatlantic shipments between conversion and enrichment facilities.



Spent fuel cask loading at Temelin NPP in Czech Republic ©ČEZ

Although the security of supply for conversion services has thus improved, SWU prices remain very low, putting under pressure some of the global enrichment capacity. If SMRs become a reality, the need for uranium fuel with higher enrichment levels (between 5% and 20%) is expected to create more demand for enrichment services.

Overcapacity also remains a concern for fuel fabrication, where world capacity is more than sufficient. Within this segment, the lack of VVER fuel supply diversification remains an issue in all EU countries operating VVER reactors. All main suppliers are developing new designs for so-called accident-tolerant-fuels, which would improve the safety of existing nuclear power plants.

It is also clear that the financial difficulties currently facing many suppliers make it more difficult to keep investing in the future and even to retain skilled staff.

Transport always remains an issue, which could lead to a short-term disruption in supply. Cross-border transport of radioactive materials has become increasingly complex and time-consuming, because of the different approaches of national regulators, port authorities and shipping companies. The main effects are interruption of and delays to consignments and, in extreme cases, shipment denials. This concern was further heightened in connection with the UK withdrawal from the EU and uncertainty over customs procedures and possible congestion at the EU/UK border crossings. In addition to a diversified supply chain, strategic inventories of nuclear materials or even ready-made fuel assemblies are the best defence against delivery delays.

Supply side — assessment of the EU situation

On the supply side, EU industry is active in all areas of the nuclear fuel supply chain. While uranium production in the EU has practically ended, new initiatives are ongoing in Spain and Finland. Resources of natural uranium located in different Member States could be considered a potential source of supply, at least in the long term.

In addition, in case of significantly higher prices and scarcity of uranium, there is a potential for increasing the use of RepU and plutonium in the EU. Currently, about 8% of the nuclear material used in fuel loaded into EU reactors comes from indigenous sources in various forms (see Table 5). As an additional reserve, significant quantities of depleted uranium are stockpiled in the EU and could either be re-enriched or used together with plutonium as MOX fuel.

For other parts of the fuel cycle (conversion, enrichment, fuel fabrication and spent fuel reprocessing), EU industry can cover most or all of the needs of EU utilities. It would be possible to expand capacity on the basis of demand; this is usually faster than building new reactors, which gives a certain reassurance for security of supply. The main challenge is to ensure the continued viability and skilled workforce of the EU industry so that the current industrial capacity, technological level and technical expertise are at least maintained and do not diminish as a result of short-term economic considerations or because other industrial sectors are more attractive to workers.

The capacity to produce fuel and components for VVER reactors in the EU is an important aspect, which still needs attention. Production capacity for VVER-1000 fuel exists in Sweden and could be expanded if necessary. Re-establishing such capacity for VVER-440 fuel manufacturing in the EU is also possible but depends on customer demand.

Demand side — assessment of the EU situation

Although demand for nuclear materials and services in the EU is falling (see Chapter 3 for details), the EU still remains the biggest regional nuclear fuel market in the world.

Current estimates provided by utilities about their future demand are conservative and based on ongoing construction projects. Several NPPs are in the planning stages in Finland, Hungary and the UK, but they are not yet included in the estimated requirements.

Natural uranium supplies to the EU are well diversified (see Table 7 in Chapter 3). Furthermore, a number of key supplier countries are politically stable and have cooperation agreements with the EU. The situation does not raise any shortage concerns in the medium term.

For conversion and enrichment services, the main three suppliers in the world are also well represented as suppliers to EU utilities. However, a prolonged closure of any of these facilities could create problems, affecting customers in the EU and elsewhere.

For fuel fabrication, the situation is different. Operators with western-design reactors can usually choose between two or even three different fuel fabricators. However, four EU countries, namely Bulgaria, Czechia, Hungary and Slovakia, which operate only VVER reactors, are currently 100% dependent on Russian suppliers of fuel assemblies. Additionally, two of the four operating reactors in Finland, accounting for 33% of the country's nuclear electricity production, are of the VVER type. Dependence on a single supplier constitutes a significant risk, as qualifying an alternative supplier could take several years because of licensing and testing requirements. In 2018, VVER-1000 operators in the EU took some positive steps in qualifying an alternative fuel supplier, but these efforts must be intensified to achieve real diversification.

Future contractual coverage rate

As detailed in Chapter 3, and taking into account the contractual coverage of EU utilities for the coming years and their inventories, EU reactor requirements for both natural uranium and enrichment services are sufficiently covered in the short and medium term.

Inventories

Most EU utilities have inventories to cover more than 2 years of operation, in different forms (natural or enriched uranium, fabricated fuel assemblies), and all utilities have sufficient inventories for at least one reload. The process of building up inventories of different chemical forms of nuclear material, and determining their appropriate level, should take into account the lead times for various steps of the fuel cycle.

In the current situation, the most vulnerable utilities in terms of security of supply remain those that depend on Russian-fabricated fuel assemblies (VVER reactors), which cannot be replaced quickly by fuel assemblies from other manufacturers. Some of these operators have increased their stocks of fuel assemblies.

Sustainability of supply

In terms of both environmental and social responsibility, the sustainability of uranium production remains a very important issue for the whole industry. An increasing number of EU utilities are including sustainability clauses in their purchase contracts, and some are following up with audits to check compliance with these clauses.

As nuclear energy generation often comes under criticism, it is very important for all parts of the industry to take sustainability seriously. It is important not only for the overall acceptability of nuclear energy, but also for creating a level playing field and for ensuring resource availability in the future. In order to develop new mines, which will be needed to fuel reactors in the coming decades, it is essential to demonstrate that uranium is produced sustainably.

In recent years, the EU has used its Instrument for Nuclear Safety Cooperation to finance remediation activities at uranium mining legacy sites in Central Asia. For new mining projects anywhere in the world, it is necessary to ensure that remediation is planned and sufficient financial provision is made for this before production starts. While this is nowadays standard practice in most producer countries, emerging producers should not neglect this aspect, which can have a critical impact on the reputation of the whole industry.

ESA findings and recommendations

Following thorough analysis of the information gathered from EU utilities at the end of 2018 (as discussed in Chapter 3), in the short and medium term, the needs of EU utilities for both natural uranium and enrichment services remain well covered on average.

In general, ESA recommends that utilities cover most of their current and future requirements for natural uranium and fuel cycle services under multiannual contracts from diverse sources of supply.

ESA continues to recommend that EU utilities maintain adequate strategic inventories of nuclear materials and use market opportunities to increase their stocks, depending on their individual circumstances. To forestall risks of shortages in the nuclear fuel supply chain, appropriate inventory levels should be maintained by both EU utilities and producers.

There has been little change in the fuel fabrication situation of VVER reactors in the EU that are 100% reliant on a single supplier, which runs counter to the EU's security of supply policy (see Figure 14). Currently, the only VVER operator with two separate suppliers of fuel fabrication services is the Ukrainian operator Energoatom. In contrast, most European non-VVER reactor operators have two separate fabricators, while some even have three.

From a security-of-supply viewpoint, there should always be at least two alternative suppliers for each stage of the fuel cycle. The second best option is to have a diversified portfolio up to the fabrication stage and maintain a strategic stock of fabricated fuel. Ideally, all utilities should hold one or two reloads of fabricated fuel assemblies for each reactor, depending on the size of their reactor fleet and other electricity generation assets. ESA welcomes the fact that some VVER operators have been increasing their stocks of fuel assemblies as an additional precaution.

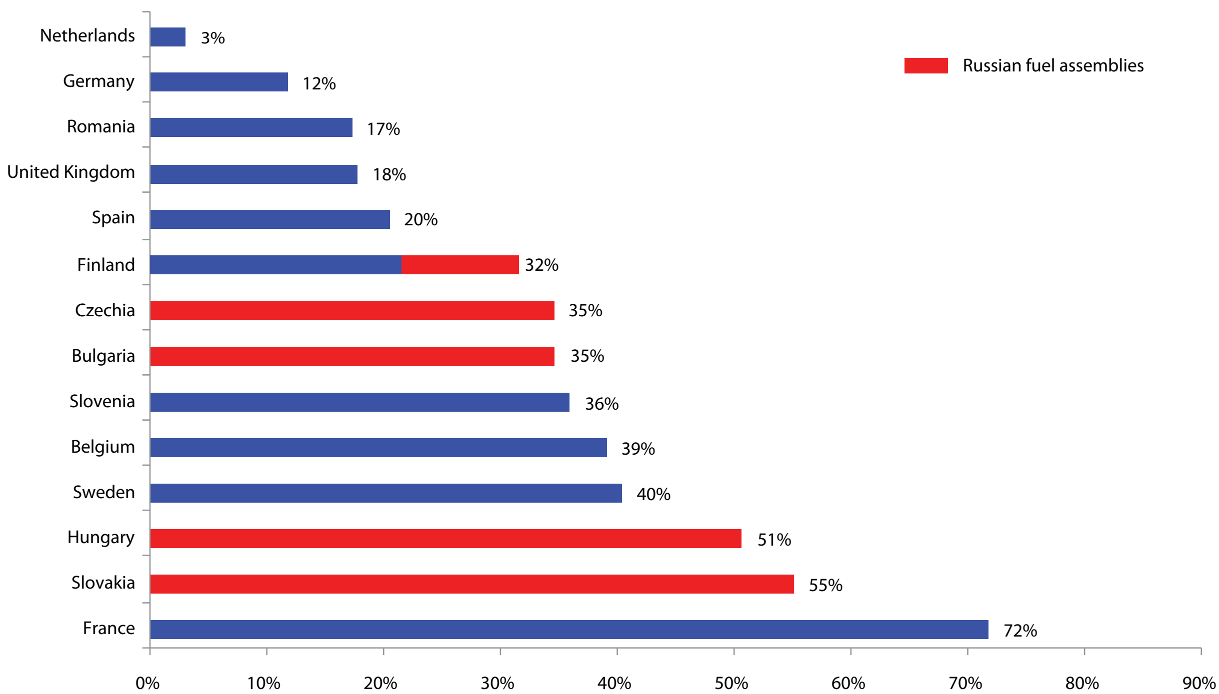
Operators should ensure that fuel supply diversification is possible for their reactors at all stages of the fuel cycle. Contracts for bundled sales of fuel assemblies (i.e. including natural uranium, conversion, enrichment and fuel fabrication) must allow the operator to provide natural or enriched uranium from an alternative supplier. For new reactors, in particular, the contract must enable the licensing and use of fuel assemblies produced by different fabricators by providing for the disclosure of fuel compatibility data and for the testing of alternative fuel assemblies.

Significant efforts have been made by Westinghouse and its eight European consortium partners under the ESSANUF project to develop a conceptual fuel design for VVER-440 fuel assemblies (see Chapter 2). ESA welcomes these efforts and recommends that VVER-440 reactor operators take concrete steps to license alternative fuel.

VVER-1000 reactor operators in the EU have initiated the process of licensing alternative fuel. These efforts are further encouraged. Closer cooperation between operators and between national regulators of countries operating VVER reactors would help to expedite the licensing process for alternative fuel.

Although these ESA recommendations are addressed mainly to utilities, it is clear that for long-term security of supply, EU producers should also maintain a skilled workforce, further develop their technology and continue to invest in their production facilities to the extent possible under the prevailing market conditions.

Figure 14. Nuclear power share of total electricity production in the EU, 2018 (%)



5. 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 for the *in vivo* diagnosis or treatment of about 30 million patients every year, including 7 million in Europe. The majority of today's nuclear medicine procedures are for diagnosis, with about 100 different imaging procedures available. Imaging using radioisotopes is often indispensable, for instance due to its ability to identify various disease processes early, long before other diagnostic tests. Technetium-99 m (Tc-99 m) is the most widely used (diagnostic) radioisotope. The production of Tc-99 m is a complex process, which includes irradiation of uranium targets in nuclear research reactors to produce molybdenum-99 (Mo-99), extraction of Mo-99 from targets in specialised processing facilities, production of Tc-99 m generators and shipment to hospitals. Due to their short decay times, Mo-99 and Tc-99 m cannot be stockpiled and must be produced continuously and delivered to hospitals weekly. Any disruption to supply can have negative and sometimes severe consequences for patients.

ESA involvement

In the light of the Council Conclusions 'Towards the secure supply of radioisotopes for medical use in the EU' dated 2010 ([55]) and 2012 ([56]), ESA's observatory role was widened in 2013 to cover aspects of the supply of medical radioisotopes in the EU. In 2018, ESA continued to coordinate activities undertaken to improve the security of supply of Mo-99/Tc-99 m and to chair the European Observatory on the supply of medical radioisotopes ([57]).

In addition, in 2018, ESA contributed to the initiative led by the European Commission's Directorate-General for Energy on the Strategic Agenda for Medical, Industrial and Research Applications of Nuclear and Radiation Technology (Samira). 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.

Core vessel and closure head for Jules Horowitz Reactor in France ©CEA

Samira covers a broad range of policy areas, and the European Commission has committed itself to working across various policy areas to enable multi-disciplinary action. A large part of this agenda focuses on the supply of medical radioisotopes. In this context, ESA actively participated in the work of the Samira Inter-Service Group to develop an action plan, and largely contributed to the preparation of the Samira Conference ([58]), particularly the dedicated session on the supply of medical radioisotope, held in Brussels in March 2018.

Follow-up of the Memorandum of Understanding between ESA and the US DoE-National Nuclear Security Administration (NNSA) on the exchange of HEU continued in 2018. ESA continued to focus on securing the nuclear material supply for research reactor fuel and targets, both for scientific research and for the production of medical radioisotopes, covering the period until the conversion of such reactors to operate with HALEU.

European Observatory on the supply of medical radioisotopes

The Observatory, which was set up in 2012, seeks to gather all relevant information to assist the decision makers of the EU

(55) http://ec.europa.eu/euratom/docs/118234.pdf
(56) http://ec.europa.eu/euratom/docs/2012_council_radioisotopes.pdf
(57) http://ec.europa.eu/euratom/observatory_radioisotopes.html
(58) https://ec.europa.eu/info/events/addressing-societal-challenges-through-advancing-medical-industrial-and-research-applications-nuclear-and-radiation-technology-2018-mar-20_en

institutions and national governments in devising strategies and the policies to implement them. It is composed of representatives of the EU institutions, international organisations and various industry stakeholders, most of which are grouped within the Association of Imaging Producers and Equipment Suppliers (AIPES) ([59]). In 2018, the Observatory held two plenary meetings, in Vienna in April and in Warsaw in October.

At the April meeting, hosted by the European Association of Nuclear Medicine (EANM) ([60]), the Observatory addressed the following topics: opportunities and challenges for nuclear medicine in Europe, research reactor scheduling and the status of HEU-LEU conversion of the European medical radioisotope production facilities. In addition, updates from the AIPES, OECD/NEA and European Medicines Agency (EMA) ([61]) were given, and the status of the European Commission projects on the supply of medical radioisotopes was provided. Discussions also focused on the updated European Research Reactor Position Paper on SustainableMo-99 Production in Europe ([62]).

At the October meeting, hosted by the Polatom company ([63]), the Observatory also discussed issues affecting the medical radioisotope supply chain, following the withdrawal of the UK from the EU, potentially leading to supply disruptions, impacting effective healthcare provision in the EU-27 and 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.

Reactor scheduling and monitoring the supply of Mo-99

The AIPES Security of Supply Working Group 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.

In 2018, the ERT was active, focusing on the outage of the NTP processing facility in South Africa, which occurred from mid-November 2017 until mid-February 2018 and then again from early June to mid-November 2018. As supply was limited during this period, shortages occurred in some regions. Therefore, the ERT performed detailed monitoring of the production of Mo-99. The ERT discussed the status on an almost weekly basis for most of 2018 and took several mitigation actions, highly contributing to ensure minimal disruptions to supply during this period.

Activated in 2017 during the NTP outage, the joint communication team (JCT) provided regular information updates to various stakeholder groups, including the EU Council's Working Party on Atomic Questions ([64]), the Health Security Committee ([65]) and the OECD/NEA High-level Group on the Security of Supply of Medical Radioisotopes (HLG-MR)[66].

Full-cost recovery mechanisms

One of the key principles of the policy approach of the OECD/NEA HLG-MR is that all participants in the Mo-99/Tc-99 m supply chain should implement full-cost recovery (FCR). This would provide the economic incentives to develop Mo-99-related infrastructure and to fully finance operating costs. FCR has to be achieved throughout the supply chain, and sufficient reimbursement should be made available to ensure a sustainable supply of Mo-99. In this respect, in 2018, the European Commission's Joint Research Centre has been carrying out a research project initiated in 2017, 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 is expected in the first half of 2019.

HEU/HALEU supply for target production and research reactor fuel

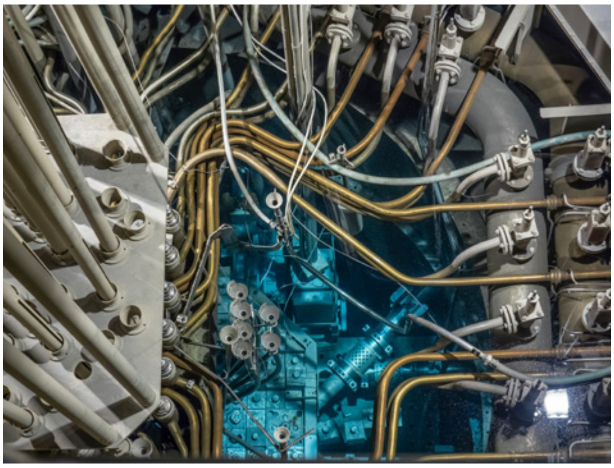
ESA continued to scrutinise the potential risks to the security of supply of HEU and HALEU for target production and research reactor fuel and to strive to obtain sufficient supplies of these materials, as neither is currently produced in the EU (the US and the Russian Federation are the only suppliers).

To that end, in close cooperation with the Member States concerned, ESA continued to facilitate the supply of HEU to users who still need it, in compliance with international nuclear security commitments. In 2018, ESA convened a meeting with the US and the Euratom Member States concerned to review progress in implementing the Memorandum of Understanding signed with the US DoE-NNSA in 2014 on the exchange of HEU needed to supply European research reactors and medical radioisotope production facilities. At the meeting, HEU quantities delivered by the US and those still required by Euratom Member States, as well as HEU quantities shipped and to be transferred to the US for downblending, were reviewed. The overall balance, as envisaged by the Memorandum, has been maintained and a significant portion of the materials identified has already been shipped to the US. Discussions also addressed

(59) http://www.aipes-eeig.org
(60) https://www.eanm.org
(61) https://www.ema.europa.eu
(62) http://ec.europa.eu/euratom/docs/European%20Research%20Reactor%20Position%20Paper%20for%20DGE%20Energy%20%202018%20report_20180801.pdf
(63) https://www.polatom.pl/en
(64) http://www.consilium.europa.eu/en/council-eu/preparatory-bodies/working-party-atomic-questions/
(65) https://ec.europa.eu/health/preparedness_response/risk_management/hsc_fr
(66) https://www.oecd-nea.org/med-radio/security/

the possibility of expanding the concept of the HEU exchange to cover other types of material, since the current inventory of unirradiated excess HEU that has been identified as eligible for the exchange is limited.

On the other hand, the medium-term availability of HALEU that is needed to supply research reactors with appropriate fuel and medical radioisotope producers with material for the production of irradiation targets, when their conversion is finalised, is still to be addressed. Following the publication in 2016 of a paper version of the report on whether it would be feasible and appropriate to build European capacity for the production of metallic HALEU ([67]), drafted in 2013 by a Working Group of ESA's Advisory Committee, a decision was taken to re-instate the Working Group to revisit the present report. The long-term availability and accessibility of HALEU is a key issue, since no appropriate production facilities for HALEU are in place (neither in the EU nor in the US). Europe must examine all alternatives to ensure the future availability of such HALEU for its needs. Without any new initiative, there is a risk for the security of supply of this critically important material after 2030-2040. The re-instated Working Group met twice in 2018 and aims at finalising the revised report in early 2019.



MARIA research reactor in Poland ©NCBJ

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 ([68]), which called upon the European Commission to identify needs for research that might be supported by the Euratom research and training programme. As a result, a research and innovation action grant (EUR 6.35 million) was awarded to the HERACLES-CP ([69]) project entitled 'Towards the conversion of high performance research reactors in Europe', coordinated by the Technical University of Munich and involving five partners. The project is scheduled to enter the new fuel type qualification phase in 2021.

A complementary project, FOREvER ([70]), 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 work programme ([71]), adopted in December 2018, included a research call on the optimised fuels for the production of medical radioisotopes, with an EU contribution of EUR 7.50 million.

(67) http://ec.europa.eu/euratom/docs/ESA-MEP-rapport.pdf

(68) http://ec.europa.eu/euratom/docs/2012_council_radioisotopes.pdf
(69) http://heracles-consortium.eu/
(70) https://cordis.europa.eu/project/rcn/210823_en.html
(71) http://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/euratom/h2020-wp1920-euratom_en.pdf

6. ESA's work programme for 2019

In line with the Agency's remit, as per Chapter 6 of the Euratom Treaty and its Statutes, ESA's work programme for 2019 is built around five specific objectives.

1. Maintaining a regular and equitable supply of ores and nuclear fuels in the European Atomic Energy Community

Since its inception, the Agency's main task has been to ensure equal access to supplies of nuclear materials for all users in the EU Member States.

ESA will continue to work for the security of supply, taking due account of the need for EU utilities to avoid excessive dependence on any single external supplier. In this regard, it will continue to engage with operators, evaluate supply contracts submitted to it for conclusion. and acknowledge transactions duly notified to it, which cover the provision of services in the entire nuclear fuel cycle or involve the transfer, import or export of small quantities of materials.

ESA will also continue to encourage the emergence of alternative sources of nuclear fuel/services supply where such sources are presently not available. ESA will continue to assess potential risks to the security of supply of HEU and HALEU, which are required to produce medical radioisotopes (Mo-99/Tc-99m) and fuel research reactors. Neither HEU nor HALEU is currently produced in the EU. During the transition from HEU to HALEU targets, and in some cases from HEU fuel to HALEU fuel, it is crucial to obtain the necessary supplies in order to prevent any shortage in the production of medical radioisotopes. ESA will actively monitor the requirements for these fissile materials and strive to ensure their supply.

The Agency is looking forward to the conclusions of its Advisory Committee's Working Group in charge of assessing the current circumstances (notably, the market conditions and business model) and updating, to the extent necessary, the Report on 'Securing the European Supply of 19.75% enriched Uranium Fuel'.

Fully complying with relevant decisions at the political level, ESA will continue to provide information and support to the European Commission and ESA's stakeholders on issues related to the UK withdrawal from the EU and the European Atomic Energy Community (Euratom). Likewise, the Agency will continue to help shape and implement, as appropriate, the contingency and preparedness measures and participate in awareness-raising efforts. In this context, ESA has been, and will continue to be, actively dealing with the consequences of the UK withdrawal on contracts under its remit.

Specific objectives

1. Exercise ESA's exclusive rights to conclude nuclear fuel supply contracts within the statutory deadline, pursuant to Article 52 of the Euratom Treaty, in line with EU policy on supply/diversification.

2. Acknowledge notifications of transactions relating to the provision of services in the nuclear fuel cycle, pursuant to Article 75 of the Euratom Treaty, in the light of EU policy on supply/diversification.

3. Acknowledge notifications of transactions involving small quantities, pursuant to Article 74 of the Euratom Treaty.

4. Encourage the emergence of alternative sources of nuclear fuel/services supply where such sources are presently not available; liaise in this respect with the operators concerned.

5. Continue to monitor the needs for HEU and HALEU, which are required to produce medical radioisotopes and to fuel research reactors; strive to ensure the supply of the materials in question. To that end, continue to liaise with both suppliers and users, including possibly non-EU ones.

6. Support the European Commission's nuclear materials accountancy staff, on request, in verifying contract data contained in prior notifications of movements of nuclear materials.

7. 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.

8. Provide contributions, in its areas of activity, to the EU negotiators and to the Commission departments in charge of contingency and preparedness measures potentially

required by the withdrawal of the UK from the EU and Euratom. Deal, in this context, with the impact of the UK withdrawal on contracts under the Agency's remit.

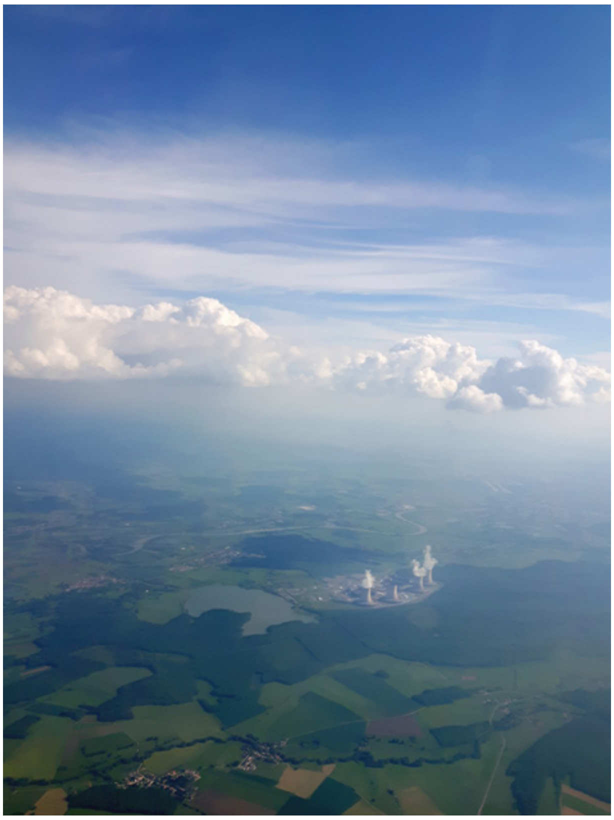
9. In line with relevant political decisions, provide information and support to its stakeholders on issues related to the UK withdrawal.

2. Observing developments in the nuclear fuel market in the context of security of supply

ESA will continue to monitor the nuclear market, including in the light of the UK withdrawal from the EU and Euratom, with a view to identifying trends likely to affect the EU's security of supply and to produce analyses and reports. In this regard, the Agency will continue to support the activities of its Advisory Committee's working groups.

Acting as the secretariat of its Advisory Committee's Working Group on Prices and Security of Supply, ESA will continue to facilitate the Group's activities to increase the transparency of the nuclear fuel cycle market in the EU.

The Agency will also continue to provide support to its Advisory Committee's Working Group, which is in charge of assessing the current circumstances (notably, the market conditions and the business model) and updating, to the extent necessary, the November 2013 Report on 'Securing the European Supply of 19.75% enriched Uranium Fuel'.



Cattenom NPP ©Niina Palomäki

The activities mentioned above lay the foundations for building up comprehensive overviews of the current state and emerging trends of the nuclear fuel cycle market. ESA's *Annual Report*, *Quarterly Uranium Market Report* and weekly *Nuclear News Digest*, circulated within the Commission, will remain the main means for presenting the Nuclear Market Observatory's analyses. ESA's website will be regularly updated, thus offering direct access to information on market developments.

In line with the mission entrusted to its Nuclear Market Observatory to cover aspects of the supply of medical radioisotopes in the EU and in order to enhance the security of supply of Mo-99/Tc-99m and possibly other radioisotopes (e.g. Lu-177), as relevant, ESA will continue to chair the European Observatory on the supply of medical radioisotopes and coordinate actions undertaken by various services involved.

Specific objectives

To deliver on its market-monitoring responsibilities, ESA will:

1. continue to support the activities of its Advisory Committee's Working Group on Prices and Security of Supply;

2. continue to provide support to its Advisory Committee's Working Group, which is in charge of assessing the current circumstances (notably, the market conditions and the business model) and updating, to the extent necessary, the Report on 'Securing the European Supply of 19.75% enriched Uranium Fuel';

3. regularly analyse the nuclear market conditions and publish, via its Nuclear Market Observatory, updated information and news, in particular the *Quarterly Uranium Market Reports*, the *Nuclear News Digest* and ad hoc studies;

4. publish its annual report, including market analyses, by July 2019;

5. continue to publish yearly natural uranium price indices: multi annual, medium-term, spot and quarterly price indices;

6. chair and lead the activities of the European Observatory on the supply of medical radioisotopes;

7. contribute, by targeted awareness-raising actions, to ensuring the continued supply of medical radioisotopes after the UK withdrawal from the EU and Euratom;

8. update ESA's website regularly, providing direct access to recent information on nuclear market developments.

3. Cooperating with international organisations and third countries

To efficiently carry out its tasks and contribute to security of supply, ESA will actively pursue its relations with international bodies.

Due to their quality and neutrality, ESA's analyses of the nuclear fuel cycle market are increasingly sought by groups of international experts. ESA will maintain regular contact not only with international nuclear organisations such as the IAEA and the NEA, but also with other international players on the nuclear fuel market. It will continue its membership of the WNA and the World Nuclear Fuel Market (WNFM).

In the interest of the continued supply of medical radioisotopes, which is part of its remit, ESA maintains contacts with EANM, AIPES, NEA and IAEA.

To ensure regular HEU supplies for as long as necessary, ESA will, as in previous years, coordinate the implementation of the Memorandum of Understanding (MoU) signed in December 2014 with the US Department of Energy/National Nuclear Security Administration (US DoE/NNSA), in cooperation with the Euratom Member States concerned. The next review meeting on the implementation of the MoU will be held in early 2019. As stated in the MoU, the Agency plans to review, in cooperation with all parties concerned, the MoU's applicability after 5 years of implementation.

Specific objectives

1. Pursue contacts with international authorities, companies and nuclear organisations.

2. Participate in the negotiation of Euratom cooperation agreements with non-EU countries and monitor the implementation of these agreements as regards trade in nuclear materials.

3. Maintain contacts with the US to ensure supply of HEU, currently still required for the production of medical radioisotopes; follow up, in this context, the 2014 MoU.

4. Review, in cooperation with the US DoE/NNSA and the Euratom Member States concerned, the applicability of the MoU after 5 years of implementation.

5. Review the conditions for covering needs for HALEU in a larger number of (EU and non-EU) countries, including possibly by setting up a European LEU facility, as suggested in the dedicated Report of the Agency's Advisory Committee.

6. Take part in the dialogue with Russia (as soon as this becomes politically feasible) on nuclear supply matters.

4. Monitoring relevant R&D activities for their potential impact on ESA's security of supply policy

ESA will continue to monitor, in the EU and international forums, nuclear technology developments which are likely to have an impact on diversification of supply or on nuclear fuel cycle management (e.g. reprocessing waste, reducing the volume of waste, improving reactor efficiency) and, thus, influence directly the nuclear fuel market.

ESA pays particular attention to, and strives to encourage (notably, in the context of Euratom framework programmes) projects to secure fuel supply for research reactors and the production of medical radioisotopes.

ESA will continue to monitor the following projects in 2019:

· HERACLES-CP, which is a HORIZON 2020 project, supported by the European Commission's Directorate-General for Research and Innovation and a central pillar of the programme for the development and qualification of high-density LEU fuel to be used in research reactors and processes, presently fuelled with HEU, after their conversion.

· FOREvER (= Fuel fOr REsEarch Reactors), which is a project to secure nuclear fuel supply for European research reactors and due to run until 2021, and which addresses both the conversion of high performance research reactors (HPRRs) from HEU to HALEU and the monopolistic supply of fuel for medium-power research reactors of original Soviet design.

Specific objectives

1. Continuously monitor technological developments relating to the nuclear fuel cycle management, with a view to adapting the Agency's security of supply policy as appropriate.

2. Review the latest technological developments relating to diversification or fuel cycle management in Advisory Committee meetings or at other meetings, where appropriate.

5. Making ESA's internal organisation and operations more effective

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

Specific objectives

1. Keep the Agency's work practices and internal control standards under review and update them where appropriate; likewise, keep under review the manual of procedures for the Contract Management and Nuclear Market Observatory sectors.

2. Start replacing the Agency's outdated IT Contract Management system.

3. Continue to ensure sound financial and budgetary management.

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This report and its previous editions are available on ESA's website:
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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/index_en.htm

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/index_en.html

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) 2019-2028

Year	Natural uranium		Separative work	
	Gross requirements	Net requirements	Gross requirements	Net requirements
2019	17 302	15 452	14 339	12 854
2020	16 869	15 118	13 936	12 735
2021	16 198	14 540	13 311	12 330
2022	16 220	14 196	13 390	12 286
2023	16 131	13 499	13 324	11 931
2024	14 851	13 028	12 162	11 226
2025	14 559	12 736	12 093	11 135
2026	14 248	12 349	12 065	11 199
2027	14 120	11 979	12 026	11 087
2028	13 658	11 539	11 746	10 973
Total	154 155	134 436	128 392	117 757
Average	15 415	13 444	12 839	11 776

(B) Extended forecast 2029-2038

Year	Natural uranium		Separative work	
	Gross requirements	Net requirements	Gross requirements	Net requirements
2029	13 663	11 454	11 537	10 699
2030	13 469	11 353	11 295	10 525
2031	13 115	11 000	11 010	10 240
2032	13 208	11 016	11 169	10 335
2033	12 600	10 485	10 639	9 869
2034	12 194	9 857	10 343	9 406
2035	12 200	9 753	10 117	9 098
2036	11 882	9 435	9 832	8 812
2037	11 874	9 537	9 838	8 901
2038	11 317	9 201	9 667	8 897
Total	125 523	103 091	105 446	96 781
Average	12 552	10 309	10 545	9 678

Annex 2
Fuel loaded into EU-28 reactors and deliveries of fresh fuel under purchasing contracts

Year	Fuel loaded			Deliveries		
	LEU (tU)	Feed equivalent (tU)	Enrichment equivalent (tSW)	Natural U (tU)	% spot	Enrichment (tSW)
1980		9 600		8 600	(*)	
1981		9 000		13 000	10.0	
1982		10 400		12 500	< 10.0	
1983		9 100		13 500	< 10.0	
1984		11 900		11 000	< 10.0	
1985		11 300		11 000	11.5	
1986		13 200		12 000	9.5	
1987		14 300		14 000	17.0	
1988		12 900		12 500	4.5	
1989		15 400		13 500	11.5	
1990		15 000		12 800	16.7	
1991		15 000	9 200	12 900	13.3	10 000
1992		15 200	9 200	11 700	13.7	10 900
1993		15 600	9 300	12 100	11.3	9 100
1994	2 520	15 400	9 100	14 000	21.0	9 800
1995	3 040	18 700	10 400	16 000	18.1	9 600
1996	2 920	18 400	11 100	15 900	4.4	11 700
1997	2 900	18 200	11 000	15 600	12.0	10 100
1998	2 830	18 400	10 400	16 100	6.0	9 200
1999	2 860	19 400	10 800	14 800	8.0	9 700
2000	2 500	17 400	9 800	15 800	12.0	9 700
2001	2 800	20 300	11 100	13 900	4.0	9 100
2002	2 900	20 900	11 600	16 900	8.0	9 500
2003	2 800	20 700	11 500	16 400	18.0	11 000
2004	2 600	19 300	10 900	14 600	4.0	10 500
2005	2 500	21 100	12 000	17 600	5.0	11 400
2006	2 700	21 000	12 700	21 400	7.8	11 400
2007 (**)	2 809	19 774	13 051	21 932	2.4	14 756
2008 (**)	2 749	19 146	13 061	18 622	2.9	13 560
2009 (**)	2 807	19 333	13 754	17 591	5.2	11 905
2010 (**)	2 712	18 122	13 043	17 566	4.1	14 855
2011 (**)	2 583	17 465	13 091	17 832	3.7	12 507
2012 (**)	2 271	15 767	11 803	18 639	3.8	12 724
2013 (**)	2 343	17 175	12 617	17 023	7.1	11 559
2014 (**)	2 165	15 355	11 434	14 751	3.5	12 524
2015 (**)	2 231	16 235	11 851	15 990	5.0	12 493
2016 (**)	2 086	14 856	11 120	14 325	3.1	10 775
2017 (**)	2 232	16 084	12 101	14 312	3.8	10 862
2018 (**)	2 225	15 912	12 075	12 835	5.0	10 899

(*) Data not available.

(**) The LEU fuel loaded and feed equivalent contain Candu fuel.

Annex 3
ESA average prices for natural uranium

Year	Multiannual contracts		Spot contracts		New multiannual contracts		Exchange rate
	EUR/kgU	USD/ lb U_3O_8	EUR/kgU	USD/ lb U_3O_8	EUR/kgU	USD/lb U_3O_8	EUR/USD
1980	67.20	36.00	65.34	35.00			1.39
1981	77.45	33.25	65.22	28.00			1.12
1982	84.86	32.00	63.65	24.00			0.98
1983	90.51	31.00	67.89	23.25			0.89
1984	98.00	29.75	63.41	19.25			0.79
1985	99.77	29.00	51.09	15.00			0.76
1986	81.89	31.00	46.89	17.75			0.98
1987	73.50	32.50	39.00	17.25			1.15
1988	70.00	31.82	35.50	16.13			1.18
1989	69.25	29.35	28.75	12.19			1.10
1990	60.00	29.39	19.75	9.68			1.27
1991	54.75	26.09	19.00	9.05			1.24
1992	49.50	24.71	19.25	9.61			1.30
1993	47.00	21.17	20.50	9.23			1.17
1994	44.25	20.25	18.75	8.58			1.19
1995	34.75	17.48	15.25	7.67			1.31
1996	32.00	15.63	17.75	8.67			1.27
1997	34.75	15.16	30.00	13.09			1.13
1998	34.00	14.66	25.00	10.78			1.12
1999	34.75	14.25	24.75	10.15			1.07
2000	37.00	13.12	22.75	8.07			0.92
2001	38.25	13.18	(*) 21.00	(*) 7.23			0.90
2002	34.00	12.37	25.50	9.27			0.95
2003	30.50	13.27	21.75	9.46			1.13
2004	29.20	13.97	26.14	12.51			1.24
2005	33.56	16.06	44.27	21.19			1.24
2006	38.41	18.38	53.73	25.95			1.26
2007	40.98	21.60	121.80	64.21			1.37
2008	47.23	26.72	118.19	66.86			1.47
2009	55.70	29.88	77.96	41.83	(**) 63.49	(**) 34.06	1.39
2010	61.68	31.45	79.48	40.53	78.11	39.83	1.33
2011	83.45	44.68	107.43	57.52	100.02	53.55	1.39
2012	90.03	44.49	97.80	48.33	103.42	51.11	1.28
2013	85.19	43.52	78.24	39.97	84.66	43.25	1.33
2014	78.31	40.02	74.65	38.15	93.68	47.87	1.33
2015	94.30	40.24	88.73	37.87	88.53	37.78	1.11
2016	86.62	36.88	88.56	37.71	87.11	37.09	1.11
2017	80.55	35.00	55.16	23.97	80.50	34.98	1.13
2018	73.74	33.50	44.34	20.14	74.19	33.70	1.18

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

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

Annex 4
Purchases of natural uranium by EU utilities, by origin, 2009-2018 (tU)

Country	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Canada	3 286	2 012	3 318	3 212	3 156	1 855	2 845	2 946	4 099	3 630
Niger	1 854	2 082	1 726	2 376	2 235	2 171	2 077	3 152	2 151	2 067
Australia	3 801	2 153	1 777	2 280	2 011	1 994	1 910	1 896	2 091	1 909
Russia	3 599	4 979	4 524	5 102	3 084	2 649	4 097	2 765	2 192	1 759
Kazakhstan	1 596	2 816	2 659	2 254	3 612	3 941	2 949	2 261	2 064	1 754
Namibia	435	1 017	1 011	1 350	716	325	385	504	923	1 046
Uzbekistan	589	459	929	159	653	365	526	115	348	166
Re-enriched tails	193	0	0	0	0	0	212	212	171	161
South Africa	426	190	113	412	17	20	1	0	0	118
United States	318	320	180	241	381	586	343	125	193	110
Other	329	432	128	256	621	299	229	130	80	80
Ukraine	10	0	284	0	0	23	0	0	0	19
EU	480	556	455	421	421	397	412	220	0	18
HEU feed	675	550	731	395	0	0	0	0	0	0
Malawi	0	0	0	180	115	125	2	0	0	0
Total	17 591	17 566	17 832	18 639	17 023	14 751	15 990	14 325	14 312	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
Grand total	222 807	24 532	16 606

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.
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 Nuclear GmbH (formerly 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
Converdyn
Itochu International Inc
KazAtomProm
Macquarie Bank Limited, London Branch
Nufcor International Ltd
NUKEM GmbH
Rio Tinto Marketing Pte Ltd
Tenex (JSC Techsnabexport)
TVEL
UEM
Uranium One
Urenco Ltd

Annex 8
Calculation method for ESA's average U_3O_8 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 order to enhance market transparency, ESA calculates three uranium price indices on an annual basis:

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

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

3. The ESA 'MAC-3' multiannual U_3O_8 price is a weighted average of U_3O_8 prices paid by EU utilities, but only under multiannual contracts which were concluded or for which the pricing method was amended in the previous 3 years (i.e. between 1 January 2016 and 31 December 2018) 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 U_3O_8 price, an indicator published on a quarterly basis if EU utilities have concluded at least three new spot contracts.

All price indices are expressed in US dollars per pound (USD/lb U_3O_8) and euros 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.

Method

The methods applied have been discussed in the working group of the Advisory Committee.

Data collection tools

Prices are collected directly from utilities or via their procurement organisations on the basis of:

- contracts submitted to ESA;
- end-of-year questionnaires backed up, if necessary, by visits to the utilities.

Data requested on natural uranium deliveries during the year

The following details are requested: ESA contract reference number, quantity (kgU), delivery date, place of delivery, mining origin, obligation code, natural uranium price specifying the currency, unit of weight (kg, kgU or lb), chemical form (U_3O_8, UF_6 or UO_2), whether the price includes conversion and, if so, the price and currency of conversion, if known.

Deliveries taken into account

The deliveries taken into account are those made under natural uranium purchasing contracts to EU electricity utilities or their procurement organisations during the relevant year. They also include the natural uranium equivalent contained in enriched uranium purchases.

Other categories of contracts, e.g. those between intermediaries, for sales by utilities, purchases by non-utility industries or barter deals, are excluded. Deliveries for which it is not possible to reliably establish the price of the natural uranium component are also excluded from the price calculation (e.g. uranium out of specification or enriched uranium priced per kg EUP without separation of the feed and enrichment components).

Data quality assessment

ESA compares the deliveries and prices reported 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 euros 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.

Despite all the care taken, errors or omissions are discovered from time to time, mostly in the form of missing data (e.g. on deliveries under options) which were not reported. As a matter of policy, ESA never publishes a corrective figure.

Data protection

Confidentiality and the physical protection of commercial data are ensured by using stand-alone computers which are connected neither to the Commission intranet nor to the outside world (including the internet). Contracts and backups are kept in a secure room, with restricted key access.

Annex 9
Declaration of assurance

I, the undersigned, Stefano Ciccarello

Acting Director-General of Euratom Supply Agency since 1 January 2019

In my capacity as authorising officer

Declare that the information contained in this report gives a true and fair view[72]*.*

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.

I hereby certify that the information provided in the present annual report and in its annexes is, to the best of my knowledge, accurate and complete.

Luxembourg, 29 March 2019

Stefano Ciccarello

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

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