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Foreword

Dear Reader,

It is my pleasure to present the Annual Report of the Euratom Supply Agency (ESA) for 2017, the second to be published during my term as Director-General.

This year's report has the same structure as the previous one. Chapter 1 includes an outline of ESA's activities in 2017 and a concise presentation of nuclear energy developments in the EU. Chapter 2 gives an overview of the world market for nuclear fuels, while Chapter 3 assesses the fuel market in the EU. It also includes an analysis of the provision of conversion services. Chapter 4 focuses on security of supply and Chapter 5 on medical radioisotopes, while Chapter 6 sets out ESA's work programme for 2018.

In line with its statutory mission, ESA continued during 2017 to assume responsibility for the EU nuclear common supply policy, in the interest of ensuring regular and equitable access to supply for EU users. Building further on close cooperation with its Advisory Committee, ESA promoted transparency and predictability in the field through the activities of the Nuclear Market Observatory.

Diversification of sources of supply has continued to be the focus of attention as a means to ensure security of supply for European users in the medium and long term. Thanks to an EU-funded project, progress has been made towards developing a conceptual fuel design intended to create a viable alternative to today's single source of fuel supply for VVER-440 power reactors.

Work following up the Memorandum of Understanding between ESA and the United States' DoE/NNSA on the exchange of High Enriched Uranium (HEU) continued in 2017, helping to ensure the supply of HEU for European research reactors and producers of medical radioisotopes, in accordance with the policy of minimising the use of HEU for civilian purposes.

2017 was also a year of change for ESA.

In line with the Commission's mandatory mobility policy for management staff, Mr Ivo Alehno, who had served for several years as Head of the Nuclear Fuel Market Operations Unit in ESA, had to leave his post in the course of the year. Mr Jussi Vihanta, Head of the Contract Management Sector and a long-serving member of the Agency's staff, assumed office provisionally, as acting head of unit. Selection procedures to appoint a new head of unit were still in progress at the end of the year.

2017 was, above all, an unprecedented year for Europe.

By letter of its Prime Minister, submitted on 29 March 2017, the United Kingdom notified its intention to withdraw from the European Union and the European Atomic Energy Community (Euratom), thus triggering the procedure under Article 50 of the Treaty on European Union.

Assuming responsibility for matters within its purview, ESA has provided expertise, information and advice to the European Commission negotiators in the context of Article 50 discussions and will continue to do so as long as this is necessary.

I have every confidence in my staff's dedication and expertise. I therefore know that ESA will continue to work to the very highest standards and will deal successfully with the challenges that lie ahead, preserving and further enhancing its status as an important contributor in its field of activity.

Marian O'Leary

Director-General of the Euratom Supply Agency

Contents

Abbreviations

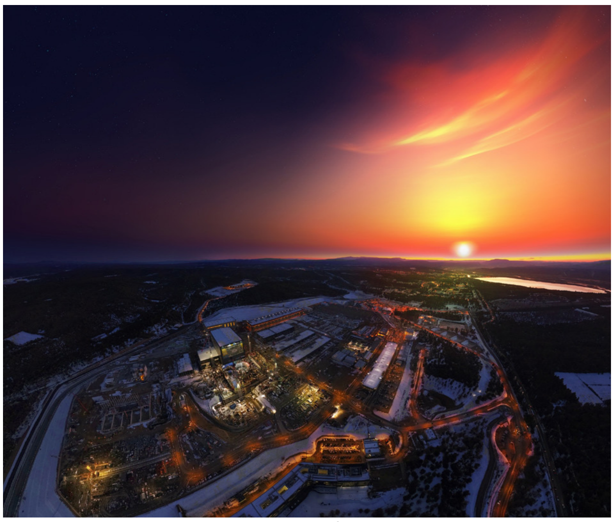
CIS	Commonwealth of Independent States
ESA	Euratom Supply Agency
Euratom	European Atomic Energy Community
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
NEA	Nuclear Energy Agency
(US) DoE	United States Department of Energy
(US) NRC	United States Nuclear Regulatory Commission
USEC	United States Enrichment Corporation
DU	depleted uranium
ERU	enriched reprocessed uranium
EUP	enriched uranium product
HEU	high-enriched uranium
lb	pound
LEU	low-enriched uranium
MOX	mixed-oxide [fuel] (uranium mixed with plutonium oxide)
RET	re-enriched tails
RepU	reprocessed uranium
SWU	separative work unit
tHM	(metric) tonne of heavy metal
tSW	1 000 SWU
tU	(metric) tonne of uranium (1 000 kg)
U_3O_8	triuranium octoxide
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 ores 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 long-term 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.



Panorama of the ITER site ©ITER Organization

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

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 values set out above. ESA implements the EU 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 2017, ESA processed 320 transactions, including contracts, amendments and notifications, and thus helped to ensure the security of supply of nuclear materials.

ESA's 2016 annual report was published on ESA's website in June 2017. As every year, ESA presented its annual calculation of different types of average natural uranium prices: MAC-3, multiannual and spot prices. In its 2016 report, ESA included for the first time information about the supply of conversion services to EU utilities. The report is available on the EU Bookshop website in paper, pdf and e-book (EPUB) versions (2).

In 2017, 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 2017, ESA issued four quarterly uranium market reports and provided for weekly updates of its nuclear news digests. The quarterly uranium market report reflects global and specific Euratom developments on the nuclear market. This in-

(2) https://publications.europa.eu/en/publication-detail/-/publication/e5927d62-6a9a-11e7-b2f2-01aa75ed71a1/language-en/format-PDF/source-66352715

cludes general data about natural uranium supply contracts concluded by ESA or notified to it, 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 2017 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, by the end of 2018, 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.


Temelin NPP turbine hall ©CEZ

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, in compliance with international nuclear security commitments. In 2017, 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 to be requested by Euratom Member States and HEU quantities to be shipped to the United States for downblending have been 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 low-enriched uranium (LEU) supply is concerned, 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 19.75 % LEU ([4]), drafted in 2013 by the Working Group of ESA's Advisory Committee, the Agency organised in November 2017 a dedicated meeting to follow up on the report. The participants agreed that the report needs revisiting and that a proposal should be made to the Advisory Committee at their next meeting in 2018 to reinstate the Working Group on Securing the European Supply of 19.75 % Enriched Uranium Fuel.

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 2017, the Advisory Committee met twice. At the first meeting on 4 May, the topics on the agenda were the Committee's opinions on ESA's 2016 annual report and on ESA's audited accounts for 2016. The Committee also discussed the progress achieved by the Working Group on Prices and Security of Supply and the follow-up to the report on securing the European supply of 19.75 % enriched uranium fuel. During the meeting, an update was given on ESA's latest discussions on the supply of HEU for research reactor fuel and targets used for medical radioisotope production, in the context of the 2014 Memorandum of Understanding on HEU exchanges referred to above.

The second meeting of the Advisory Committee, on 12 October, marked the beginning of the new three-year mandate of its members, following the expiry of the previous Committee's term of office. The meeting started with the election of the Chair and Vice-Chair. The Committee decided to reinstate the Working Group on Prices and Security of Supply and approved its work programme. In addition, the committee also discussed the future European supply of 19.75 % LEU, in the context of the Advisory Committee Working Group's report on whether it would be feasible and appropriate to build European capacity for the production of metallic 19.75 % LEU. It was agreed that ESA would convene a dedicated working meeting of interested parties to follow up on the report. During the Advisory Committee meeting, the representatives of Member States presented updates on developments in their countries and the European Commission's Directorate-General for Energy outlined the main aspects of several Euratom directives adopted or amended during 2006-2014, in particular, on the safe management of spent fuel and radioactive waste. The Committee took note of the updates provided on the draft budget of ESA for the 2018 financial year and on ESA's work programme for 2018. The

(3) http://ec.europa.eu/euratom/observatory_radioisotopes.html.

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

committee also provided a favourable opinion on the estimate of ESA's revenue and expenditure for the 2019 financial year.

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 2017, ESA continued its cooperation with both these organisations by participating in two working groups, the joint NEA/IAEA Uranium Group (5) and the NEA High-Level Group on the Security of Supply of Medical Radioisotopes (HLG-MR) (6), as well as in the Nuclear Development Committee (NDC) (7). At the joint NEA/IAEA Uranium Group meeting in November 2017, ESA presented its latest analysis of the EU nuclear market. ESA also represented the European Observatory on the Supply of Medical Radioisotopes at the HLG-MR meetings held in February and July 2017. In September 2017, ESA took part in the World Nuclear Association (WNA) Symposium, the global nuclear industry's annual event.

In addition, in 2017 ESA joined the newly created NEA Expert Group on Uranium Mining and Economic Development (8) and participated in its kick-off meeting held in October.

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 (9) and the accounting rules and methods established by the European Commission.

Article 1(2) 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 2017, the assets owned by the Agency totalled EUR 637 046. They were financed by liabilities of EUR 3 362 (1 %) and equity of EUR 633 684 (99 %). The Agency has 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 2017, 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 2017 presented a small decrease at EUR 123 000 (EUR 125 000 in 2016), due to the lower revenues from own investments (a bond expiration in 2016 and the negative prevailing interest rate environment). 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 119 000 in 2016).

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

(5) http://www.oecd-nea.org/ndd/uranium.
(6) http://www.oecd-nea.org/med-radio/security/.
(7) http://www.oecd-nea.org/ndd/ndc/.
(8) https://www.oecd-nea.org/ndd/groups/umed.html

(9) Regulation (EU, Euratom) No 966/2012 of the European Parliament and of the Council on the financial rules applicable to the general budget of the Union and repealing Council Regulation (EC, Euratom) No 1605/2002 (OJ L 298, 26.10.2012), and in particular Article 1(2) thereof.

ESA's financial statements from 31 December 2017 show a budget execution of EUR 121 621, or 99 % of commitment appropriations (against 94 % in 2016). 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 2017, 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 2016 financial year.

Discharge

The European Parliament, acting on a Council recommendation, is the discharge authority for ESA. On 27 April 2017, the European Parliament granted ESA's Director-General discharge for the implementation of the budget for the 2015 financial year ([10]).

Staff

During 2017, ESA's Head of Unit post became vacant and will be filled in 2018. At the end of the year, ESA had 17 permanent posts. ESA staff are European Commission officials, in accordance with Article 4 of ESA's Statutes ([11]).

EU nuclear energy policy in 2017

A number of measures were taken at EU level to implement and further develop the framework for nuclear safety, security, non-proliferation and radiation protection.

Strategic agenda for nuclear energy

As part of the implementation of the Energy Union Strategy ([12]) and in accordance with Article 40 of the Euratom Treaty, the European Commission adopted the latest Nuclear Illustrative Programme (PINC) ([13]) in May 2017. It provides a full overview of developments and investments needed in the nuclear field in the EU for each step of the nuclear lifecycle with a 2050 horizon.

In 2017 the European Commission's Directorate-General for Energy continued its work on a proposal to update the notification requirements for nuclear investment projects under Article 41 of the Euratom Treaty. The initiative aims to take into account the challenges and concerns related to security of supply and to ensure full compliance with Euratom safety requirements. It also aims to make the notification procedure more efficient and provide greater transparency to all stakeholders.

Euratom legislation

Work continued in 2017 to ensure timely transposition and effective implementation of the EU legal framework on nuclear safety, responsible and safe management of spent fuel and radioactive waste, and the radiation protection of workers and the general public.

The European Commission has been supporting the Member States in transposing the amended Nuclear Safety Directive ([14]), the revised Basic Safety Standards Directive ([15]) and the Euratom Drinking Water Directive ([16]) into national law. The Commission's support includes bilateral meetings, the organisation of dedicated workshops and assessments of national draft legislation notified under Article 33 of the Euratom Treaty.

Under Directive 2011/70/Euratom for the responsible and safe management of spent fuel and radioactive waste([17]), efforts were focused in 2017 on the Commission's assessment of the notified transposition measures, national programmes and first reports on implementation of this Directive.

Nuclear safety

The European Commission provided support to Member States and nuclear regulators (inter alia through a specific workshop) on the implementation of the nuclear safety objective enshrined in the amended Nuclear Safety Directive. Steps were also undertaken, in coordination with the European Nuclear Safety Regulators Group (Ensreg), to launch the effective implementation of the first topical peer review under the Nuclear Safety Directive on 'ageing management of nuclear power plants', which was officially launched in February 2017. Participating countries were requested to submit their report to the European Commission and Ensreg by 31 December 2017 for publication on the Ensreg website ([18]). All reports were pub-

(10) European Parliament decision of 27/4/2017 (P8_TA-PROV (2017)0181, 2016/2183(DEC)).
(11) 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.
(12) https://ec.europa.eu/priorities/energy-union-and-climate_en.
(13) https://ec.europa.eu/energy/sites/ener/files/documents/nuclear_illustrative_programme_pinc_-_may_2017_en.pdf

(14) OJ L 219, 25.7.2014, pp. 42-52.
(15) OJ L 13, 17.1.2014, pp. 1-73.
(16) OJ L 296, 7.11.2013, pp. 12-21.
(17) OJ L 199, 2.8.2011, pp. 48-56.
(18) http://www.ensreg.eu/country-specific-reports

lished by early January 2018. A peer review workshop will take place in May 2018 and the peer review report is expected to be published in mid-2018.

Safe management of radioactive waste and spent fuel

The European Commission adopted in May 2017 its first report to the European Parliament and the Council on the implementation of the Directive for the responsible and safe management of spent fuel and radioactive waste ([19]). The report presents a comprehensive overview of the current situation of spent fuel and radioactive waste management in the EU, including an inventory of waste present on the EU's territory. The report contributed to an informed and transparent discussion on safe and responsible management of the back-end of the fuel cycle, including shared disposal, in an effort to avoid undue burdens on future generations. Following the adoption of the report, a number of events took place dedicated inter alia to addressing waste management. The events included the 2017 European Nuclear Energy Forum (ENEF), the 2017 Ensreg Conference and the Commission's workshop with Member States. The Commission has already identified a number of follow-up actions for implementation in the period 2017-2018, with focus on inventories, cost assessments and financing mechanisms for management of spent fuel and radioactive waste. Some of the actions above also respond directly to the recommendations made by the European Court of Auditors in its 2016 audit of the decommissioning financing.

EU support for nuclear decommissioning assistance programmes

In June 2017, the Commission presented to the European Parliament and the Council the third report on the implementation of the nuclear decommissioning assistance programme to Bulgaria, Lithuania and Slovakia ([20]). It also adopted the 2017 annual work programmes and associated financing decisions, allocating EUR 138 007 million for their implementation. In 2017 the programmes were assessed with the aim of preparing the mid-term evaluation report to the European Parliament and the Council. In line with expectations set for the current multiannual framework, Bulgaria, Slovakia and Lithuania have progressed effectively and efficiently in the decommissioning of their reactors.

Radiation protection

Five verification missions of Member States' radioactivity monitoring facilities were carried out during 2017 under Article 35 of the Euratom Treaty. In addition, 12 Commission opinions were delivered on general data submitted by Member States on plans for the disposal of radioactive waste pursuant to Article 37 of the Euratom Treaty. All Article 36 declarations by Member States on discharges of radioactive substances into the environment for the year 2016, as per Commission Recommendation 2004/2/Euratom, were validated and uploaded in the RADD database (on the Europa website) ([21]).

In the field of nuclear emergency preparedness and response, the activities of the European Commission's Directorate-General for Energy focused on ensuring consistent implementation of the Basic Safety Standards ([22]) and Nuclear Safety Directive requirements. A study was concluded to enable Member States to achieve better consistency in their emergency planning and response, in particular for cross-border issues.

In the field of non-power applications of nuclear and radiation technology, the European Commission's Directorate-General for Energy launched a study on medical, industrial and research applications of nuclear and radiation technology. Furthermore, a conference on the same subject will be organised in March 2018 as part of the preparatory work for the development, by the end of 2018, of the Samira project.

European Nuclear Energy Forum

The ENEF conference was held in Prague in May 2017 ([23]). On the occasion of the 60th anniversary of the Euratom Treaty, the discussion, which included participants from various backgrounds, focused on the strengths, weaknesses and future potential of the Treaty. In addition, there were dedicated sessions on safe and responsible radioactive waste and spent fuel management, and on the potential offered by standardised supply chains. The continued participation of NGOs in ENEF in the last couple of years helped to enhance the quality of the debate and increased the opportunities for an open exchange of views.

European Nuclear Safety Regulators Group

Ensreg held its fourth conference in Brussels in June 2017. The conference brought together around 270 delegates including national regulators, NGOs, nuclear operators and academics. This successful conference focused on upcoming challenges such as long-term operation and supply chain control.

(19) https://ec.europa.eu/transparency/regdoc/rep/1/2017/EN/COM-2017-236-F1-EN-MAIN-PART-1.PDF
(20) http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52017DC0328&from=EN
(21) http://europa.eu/radd/
(22) OJ L 13, 17.1.2014, pp.1-69.
(23) https://ec.europa.eu/energy/en/events/european-nuclear-energy-forum-enef-plenary-meeting

Convention on Nuclear Safety

The Euratom report on the implementation of the Convention on Nuclear Safety (CNS) (24) was presented at the seventh review meeting of the contracting parties to the Convention, which took place in Vienna in March and April 2017 (25). The European Commission successfully tabled a Euratom written statement in agreement with the Member States, reflecting the value of the safety objective enshrined at EU level in the Nuclear Safety Directive, and calling for swift implementation of the Vienna Declaration on nuclear safety by all state parties to the Convention. The Euratom report on the implementation of the Joint Convention on the management of radioactive waste and spent fuel, in view of the sixth review meeting in May 2018, was submitted to the IAEA in October 2017.

Stress tests

The European Commission's Directorate-General for Energy continued its efforts to support implementation of risk and safety assessments (stress tests) (26) of nuclear power plants in countries neighbouring the EU, in close collaboration with the Joint Research Centre. Work in 2017 focused, in particular, on preparations to implement stress tests for the Ostrovets nuclear power plant in Belarus. The Belarusian authorities submitted the national stress test report to Ensreg and the European Commission in October 2017. Agreement was reached during the year on the practical arrangements for conducting the peer review on the national stress test report in 2018.

Joint Comprehensive Plan of Action

In support of the implementation of the Joint Comprehensive Plan of Action (JCPoA) (27) with Iran, the European Commission organised two high-level seminars with Iranian decision makers addressing the themes of nuclear governance, nuclear safety and waste management and international nuclear cooperation. A follow-up high-level seminar is planned for late 2018, and other working-level contacts and events will take place during 2018.

International Thermonuclear Experimental Reactor (ITER)

On 14 June 2017, the European Commission published the Communication entitled 'EU contribution to a reformed ITER (28) project' (29), in which it confirmed its support for the project and launched interinstitutional discussions with the Council of Ministers and the European Parliament on the new ITER baseline (cost, schedule and scope) with a view to obtaining a mandate authorising the European Commission to approve the new baseline at Ministerial ITER Council level, possibly in 2018.

On 6 July 2017, the Directorate-General for Energy finalised a comprehensive strategy to improve the supervision and governance of the Fusion for Energy (F4E) Joint Undertaking (30) after constructive feedback received from F4E. The strategy sets out the supervision needs and objectives, as well as the tools, working methods and procedures needed to achieve them. Based on this strategy an updated administrative agreement with F4E is now under negotiation, to be finalised in the first half of 2018.

Complementary to the supervision strategy for F4E, the European Commission has redesigned a comprehensive supervision strategy for Euratom's participation in the governance of the ITER Organisation that will be implemented during 2018. This strategy focuses on improving the role of the ITER Council in steering the Organisation and also in supervising its performance.

The works at the ITER site are progressing well, under a demanding schedule and in the technically challenging context of a first-of-its-kind project. The 21st ITER Council meeting of 15-16 November 2017 confirmed that the project remains on schedule to start generating plasma (an essential component in nuclear fusion reactors) in 2025. The ITER Organisation also announced in late November that the project had reached 50 % completion of the total physical work (design, manufacturing construction, assembly, installation) needed for generating plasma.

The European Commission's Directorate-General for Energy organised an 'ITER Industry Day' (31) on 4 December 2017, attended by over 100 policymakers, senior company executives and energy experts from Europe and the rest of the world. The event demonstrated that ITER is already having a positive impact on jobs, growth and innovation, in particular for the European industries and SMEs involved in the conception and construction of the thousands of first-of-their-kind technological components of this project. Over the last 10 years, F4E has directly awarded over 1 000 contracts and grants with a value of approximately EUR 4 billion, spread all over Europe.

(24) http://www-ns.iaea.org/conventions/nuclear-safety.asp.
(25) https://www-ns.iaea.org/downloads/ni/safety_convention/7th-review-meeting/euratom_nr-7th-rm.pdf
(26) https://ec.europa.eu/energy/en/topics/nuclear-energy/nuclear-safety/stress-tests
(27) http://eeas.europa.eu/archives/docs/statements-eeas/docs/iran_agreement/iran_joint-comprehensive-plan-of-action_en.pdf.
(28) https://www.iter.org/.
(29) https://ec.europa.eu/energy/sites/ener/files/documents/eu_contribution_to_a_reformed_iter_project_en.pdf
(30) http://fusionforenergy.europa.eu/
(31) https://ec.europa.eu/energy/en/events/iter-industry-day

Main developments in the EU

The UK's withdrawal from the EU

The United Kingdom submitted on 29 March 2017 notification of its intention to withdraw from the EU, including Euratom, pursuant to Article 50 of the Treaty on European Union. Negotiations are ongoing with the UK on the withdrawal agreement. Unless a ratified withdrawal agreement establishes another date, all EU primary and secondary law will cease to apply to the UK from 30 March 2019.

From the withdrawal date, the UK will have sole responsibility for ensuring compliance with its international obligations arising from its membership in the IAEA and from various international treaties and conventions to which it is a party. In particular, the UK must establish its own nuclear safeguards regime and negotiate bilateral nuclear cooperation agreements with the various nations now covered by Euratom agreements, including Australia, Canada, the US and Japan.

Country-specific developments in 2017

Belgium: In May, the Belgian Federal Agency for Nuclear Control gave Engie Electrabel approval to restart Unit 1 at Tihange NPP. The Unit was again taken offline in September for unplanned operational maintenance, combined with a previously scheduled 50-day annual maintenance and refuelling outage.

In July, the European Commission cleared a Belgian law envisaging the creation of a state guarantee programme to cover nuclear damage from nuclear power accidents that cannot be covered by private insurance. Under this programme, the nuclear operator will pay an annual premium to benefit from the state guarantee. In the Commission's view, the provision does not violate EU State aid rules and aims to ensure Belgium's compliance with the amended Paris Convention on nuclear third-party liability. Under the Belgian law, an NPP operator would have to compensate victims up to a value of EUR 1.2 billion for injuries to persons and property damage, and for environmental damage and economic losses for up to 30 years after a nuclear incident occurred.

In November, the government received a joint statement from three major Belgian business associations, calling on it to keep at least two of Belgium's NPPs open after 2025. The decision would be in line with the country's goals of ensuring security of supply, affordable prices, reduced CO_2 emissions and maintaining domestic nuclear know-how.

Bulgaria: Although there is no official government decision to restart Belene NPP, the project has been put back on the Bulgarian energy agenda. After satisfying the Russian financial claims concerning the contracted NPP equipment, all the reactor-related components except the steam-generators have been delivered to Bulgarian territory and currently are being stored at the Belene site in full conformity with the national legislation and the manufacturer requirements. In November 2017, the Bulgarian Academy of Science presented a comprehensive analytical report which assessed the project's economic viability and considered various project implementation scenarios and financial schemes. Based on the report's findings and based on the Decision of the National Assembly from 2 March 2018, by the end of June 2018 the Minister for Energy should prepare concrete proposals on different options for project assets realisation, including analysing the possibility for establishing a separate legal entity. A dedicated task force has been set up to implement the decision under the governance of the Ministry of Energy.

In November 2017, Unit 5 at the Kozloduy NPP received a 10-year licence extension from Bulgaria's Nuclear Regulatory Agency. The 30-year design lifetime reactor has been in operation since 1987. During recent years, the reactor has undergone a comprehensive modernisation programme so that it can remain operational until 2047. Unit 6 at Kozloduy NPP, licensed to operate until 2019, is presently also undergoing a comprehensive modernisation programme in preparation to extend its lifetime.

Czech Republic: In January 2017, the Czech government agreed in principle to consult local government councils over the choice of location for a deep underground disposal site for high-level nuclear waste, but a final proposal on how those consultations should be organised has been delayed until mid-2018. In July 2017, the State Office for Nuclear Safety, the Czech nuclear regulator, announced it had authorised an extension of the operating licence of CEZ's Dukovany Unit 2. In December, the operating licences of Dukovany units 3 and 4 were similarly extended. It means that operation of all four units is not currently limited by time, although they have to meet numerous requirements for further operation (e.g. periodic safety reviews).

As regards the project to add one new reactor at the Dukovany NPP, nuclear power companies from the US, Russia, Japan, France, China, and South Korea provided feedback to the request for information issued by Ministry of Industry before the end of 2017. CEZ reported in November that it had applied to the local Ministry of Environment for an environmental impact assessment clearance for new reactors at the Dukovany site.

Research Center Rez, the research arm of Czech nuclear industry and engineering company UJV Rez, is looking into developing SMRs, as a means of maintaining and developing national nuclear expertise.

Germany: PreussenElektra's Isar-1 Unit and EnBW's Neckarwestheim-1 Unit became the first reactors in Germany to receive a decommissioning and dismantling licence, issued by the Ministry of Environment of their respective states.

On 20 July 2017, the amendment to the Act on the search for and selection of a site for disposal of heat-generating radioactive waste and for the amendment of other laws (Site Selection Act, StandAG) entered into force. The Act now contains the implementation of the recommendations of the Committee on the Storage of High-Radioactive Waste Materials (Endlagerkommission). The aim of the open-ended site selection procedure under this Act is to conduct a science-based, transparent procedure to find a site for a final repository by 2031, in particular for highly radioactive waste. The procedure starts from a 'blank canvas' with no pre-ordained stipulations and includes the controversial Gorleben salt mine.

In June, Germany's Supreme Court ruled that the nuclear fuel tax applied between 2011 and 2016 was void because it was deemed inconsistent with the Federal Constitution. Subsequently, the country's remaining nuclear operators, RWE, E.ON's PreussenElektra Unit and EnBW, received refunds for the taxes paid during those five years.

On 16 June 2017, the Act reorganising responsibility for nuclear waste management entered into force. The Act implements the recommendations of the Committee Reviewing the Financing for the Phase-out of Nuclear Energy (KFK). The Act allocates responsibility for nuclear waste management and ensures the long-term financing of shutdown, dismantling and disposal, without passing the related costs on to the taxpayers alone or jeopardising the economic situation of the operators. Under the Act, the responsibility for the management and financing of the shutdown and dismantling of NPPs and of packaging the nuclear waste continues to lie entirely with the NPP operators. However, the State bears all operational and financial responsibilities in relation to the storage and disposal of nuclear waste, while the NPP operators had the obligation to provide the funds for the financing of the storage and disposal of nuclear waste. On 3 July 2017, the operators transferred a total of approximately EUR 24.1 billion to a public-law fund established with the entry into force of the Act on the reorganisation of responsibility in nuclear waste management. The funds provided by the NPP operators consisted of a so-called 'basic amount' of around EUR 17.93 billion in total, and an optional risk premium amounting to a total of around EUR 6.21 billion, paid by the NPP operators so that they are not obliged to provide additional capital to the public fund in the event of unexpected additional costs in the future.

On 26 June 2017, the German government and the energy utilities operating in Germany signed a contract confirming the division of responsibility as set out in the Act reorganising responsibility for nuclear waste management. The contract provides long-term legal certainty for both the Federation and the utilities and puts an end to a number of legal disputes between energy companies and the State on matters linked to nuclear waste management and the nuclear phase-out.

RWE's Unit B at the Gundremmingen NPP in Bavaria was shut down permanently on 31 December after 33 years of operation. Unit C of the NPP will continue to operate until 2021. In line with the country's nuclear power phase-out policy, the remaining seven reactors will be gradually closed by the end of 2022.

Spain: According to official statements issued end-March, the Regional Assembly of the government of Valencia has approved a political non-binding motion to close the 1 092-MW Cofrentes reactor. In addition, the Spanish government has refused to renew the operating permit of the country's oldest nuclear plant, the 466-MW Garoña, which has been shut down since 2012. According to the Spanish Ministry of Energy, Tourism and the Digital Agenda, Garona's capacity was too small to cause any considerable effect on the market.

Nevertheless, the Spanish government will determine the future of nuclear power in Spain as part of the electricity mix through the approval of a comprehensive energy and climate plan that will enable Spain to comply with its EU environmental commitments.

To that end, the government set up in July 2017 an expert commission on energy transition. The mandate for this Commission is to prepare a report to guide the strategy needed to meet European energy and climate objectives, taking into account efficiency and sustainability criteria such as job creation, competitiveness of the economy and environmental issues. The report will contain proposals for existing energy policy alternatives — including nuclear — and their associated costs and benefits. Based on its results, the government will adopt the comprehensive energy and climate plan with an energy mix scenario setting out the contribution of each energy source to the electricity mix.

Berkeley Energia Ltd announced in August that it had entered into an agreement with the sovereign wealth fund of the Sultanate of Oman for an investment of up to USD 120 million to fully fund the Salamanca mine so that it could begin production. On 12 December, the company reported that it had signed all the necessary contracts for the mine, plant and associated infrastructure. Currently, the Retortillo project still has to obtain some authorisations from the Spanish authorities, including a construction permit from the Ministry of Energy, Tourism and Digital Agenda. However, the procedure for issuing the permit is suspended until the mandatory report from the Nuclear Safety Council has been issued. The permit is needed before the mine can be built and put into operation.

France: In January, the Nuclear Safety Authority (ASN) granted EDF authorisation to restart 9 out of its 12 pressurised water reactors (PWRs) that had been offline at the end of 2016.

New Areva and China National Nuclear Corp. (CNNC) signed in February a framework agreement for industrial and commercial cooperation over fuel cycle activities and negotiations on a reprocessing plant.

On 24 March, the Ministry of the Environment, Energy and the Sea, with support from the ASN, issued a decree to extend to 11 April 2020 the deadline for EDF to commission the 1 650-MW Flamanville-3 reactor. Despite a series of construction-related delays, there is confidence that the operator will be able to complete the project. This is, however, subject to the conclusions of ongoing enquiries, especially those related to anomalies in the vessel bottom of the reactor. EDF conducted during 2017 a comprehensive review of manufacturing records relating to components manufactured at Areva's Le Creusot Forge. The facility had been out of operation since December 2015 due to quality assurance issues following the discovery of an anomaly in the composition of the steel in the pressure vessel of the Flamanville-3 EPR under construction. Following the review of 12 reactors equipped with such components, EDF issued on 14 September a first progress report and declared that it had identified 471 anomaly reports. However, it considers that none of the anomalies are liable to compromise the safe operation of the affected components. Flamanville-3 should be connected to the grid for the first time in May 2019 and reach full-power output in November.

In a report released early July, IRSN (Institut de Radioprotection et de Sécurité Nucléaire), the technical arm of ASN, declared the nuclear waste agency Andra's proposal for a French geological disposal facility to be satisfactory from a technical point of view. IRSN underlined, however, that the proposed facility's architecture could be optimised to avoid radiation leakage into the environment, and also made recommendations on risk monitoring during operations, preparedness in case of potential contamination and fire preparedness. Andra is expected to ask for ASN's approval of the facility by the end of 2018 and then, separately, obtain the final construction permit.

In July, the French government completed the purchase of EUR 2 billion worth of additional shares in Areva SA, and an additional EUR 2.5 billion of equity in NewCo, the company's fuel cycle business. Control of New NP, Areva's reactor business, was sold to French state-controlled utility EDF. Liabilities from completing Olkiluoto-3 in Finland and issues surrounding the fabrication of a reactor vessel head for another EPR project have remained with Areva SA.

The restructuring process continued, including the acquisition by foreign companies of shares in the different newly created companies. At the end of the year, New Areva NP announced that it had officially changed its name back to Framatome, the name previously held by the French reactor company prior to its merger with Cogema in 2001. Mitsubishi Heavy Industries (MHI) has completed the acquisition of a 19.5 % stake in Framatome, and Assystem has acquired the remaining 5 % share. The newly created Framatome includes most of the reactor business formerly owned by Areva except for contracts for the Olkiluoto EPR and certain contracts related to the Le Creusot forge facility. The new company also includes Areva's fuel fabrication business

A decision to go ahead with the French advanced sodium technological reactor for industrial demonstration, or Astrid, is now expected no sooner than 2019, with construction to start in 2022 and operations to begin around 2030. According to CEA, the basic Astrid design, initially planned to be completed in 2017, will be presented in 2019.

According to official statements released in November, the government will postpone the deadline for reducing nuclear power's share in the French electricity mix to 50 %, compared to the current 75 %. The previously set target of 2025 might only lead to increases in fossil fuel electricity generation and put at risk the whole electricity system of France. A new deadline to reduce to 50 % the share of nuclear power in the electricity mix has not been set yet.

Hungary: In March, the European Commission approved under EU State aid rules Hungary's plan to provide financial support for the Paks II project, which consists of two planned VVER-1200 reactors at the Paks NPP. Hungary's Atomic Energy Authority also announced end-March that it had approved an application for a site licence for the proposed project. According to official government statements issued in September, preliminary site work on the project would begin in 2018, with construction due to start in 2020. The first of the two 1 000 MW Russian VVERs would enter commercial operation in 2026 and the second in 2027. In December, the Hungarian Atomic Energy Agency granted Paks I- Unit 4 a 20-year extension of its lifetime.

Lithuania: In June, the Lithuanian nuclear regulator VATESI granted the newly created solid radioactive waste management and storage facility an operating licence to start testing using radioactive materials. Located on the site of the closed Ignalina NPP, the facility will house low-level and intermediate-level nuclear waste and will operate for 50 years.

Poland: In July, a Polish government delegation visited China General Nuclear Power Corp., China's largest nuclear power producer, to discuss potential cooperation on building Poland's first NPP. The parties also signed a memorandum of understanding on cooperation in civil nuclear energy. Latest official statements from the government indicate the country should build three nuclear power reactors with a combined capacity of 4.5 GW to meet the EU clean energy targets. The first of the units could begin commercial operation in 2029-2030 and the third in 2040-2043.

Romania: In May, the Council of the Organisation for Economic Cooperation and Development invited Romania to join the Nuclear Energy Agency, with full membership accession formalised in an exchange of letters with the OECD Secretary-General in June.

Slovakia: Westinghouse Electric Company signed a contract with Jadrová a vyraďovacia spoločnosť (Javys, a.s.) for an EBRD (European Bank for Reconstruction and Development)-financed project to dismantle the reactor coolant systems of two VVER-440 units at the Bohunice V1 NPP. Units 3 and 4 at the Mochovce NPP should be completed according to schedule in 2018 and 2019 respectively, without further delays. Slovenske Elektrarne reported in November that Unit 3 was 96 % completed and Unit 4 84.4 % finished.

Finland: Construction on Fennovoima's planned NPP in northern Finland faced delays in 2017, as the Finnish Nuclear Safety Authority reported it would not issue a safety assessment and building permit earlier than the end of 2018.

In May, the Teollisuuden Voima Oy power company (TVO) publicly announced that it had withdrawn its lawsuit in France against Areva relating to the completion of the Olkiluoto-3 reactor. However, in September, it filed an appeal before the

European Court of Justice against the European Commission's decision of January 2017 to approve the French State's financing of the Areva restructuring process. The Finnish utility wants to be sure that sufficient financial and human resources are available to complete the Olkiluoto-3 project, which is currently around EUR 8.5 billion over budget and nine years behind schedule, and to ensure its future operation.

After successfully performing cold function tests for Olkiluoto 3, TVO reported in December that hot functional testing had officially commenced at the EPR project. These tests comprise a critical part of the reactor's commissioning and are expected to take several months to complete. The unit is expected to enter commercial operation in early 2019.

Terrafame, owner of Finland's Sotkamo mine, announced on 18 December that the Finnish Radiation and Nuclear Safety Authority (STUK) had issued it with a permit for a lab-scale pilot programme to research the extraction process of recovering uranium from Sotkamo ores.

Sweden: OKG, operator of the Oskarshamn NPP, decided to permanently close Unit 1 ten days ahead of the 29 June scheduled date, as the reactor experienced an issue that led to an automatic shutdown. Oskarshamn Unit-2 is set for early closure in 2019 or sooner. As for the operation of Unit-3, OKG decided to invest SEK 865 million (around EUR 86 million) in an independent core cooling system required for all Swedish reactors by the Swedish Radiation Safety Authority (SSM), if licensees want to continue operating units beyond 2020.

Mid-2017, Vattenfall declared its intention to spend SEK 2 billion (around EUR 200 million) on reactor upgrades in 2017, mainly in the Ringhals Units 3 and 4 and the three units at the Forsmark NPP. The utility intends to continue operating those units until the end of their technical lifetimes, which is estimated to be 60 years of operation.

An audit report by the Swedish National Audit Office concluded that the Swedish Radiation Safety Authority had badly managed the fees levied on the country's nuclear reactor operators, insufficiently following up on how the fees were used. As a result, the fees will be reduced by a total of 20-25 % for the next 5 years.

United Kingdom: The UK Office for Nuclear Regulation (ONR) and the Environment Agency announced on 30 March their common conclusion that the Westinghouse AP1000 reactor design is suitable for use in the UK. Uncertainties have emerged, however, with regard to the successful completion of NuGen's plans to build up to three Westinghouse AP1000 reactors at the Moorside site: since Westinghouse announced its strategic restructuring on 29 March, ENGIE made public its decision to sell its 40 % stake in the NuGen venture to Toshiba, followed by rumours that Korea Electric Power Company (KEPCO) was considering purchasing a 60 % stake in NuGen from Toshiba-Westinghouse.

End of March, EDF Energy announced progress with regard to the Hinkley Point C, as concrete had been poured for power station galleries following approval from the ONR.

Horizon Nuclear Power announced in April that it had applied to the ONR for a site licence for its 'Wylfa Newydd' (New Wylfa) project. Following a 19-month evaluation period, ONR should determine whether Horizon is able to meet the safety requirements necessary to obtain the licence.

Hitachi Ltd is looking to sell part of its 100 % stake in the Horizon Nuclear Power Ltd UK nuclear development company, even before a final investment decision is made to proceed with Horizon's proposed 2 700-MW NPP in north Wales. ONR was expected to complete by year-end its generic design assessment of the UK ABWR design that would be built at Wylfa Newydd. Hitachi will be doing some maintenance and other contract work at the Wylfa Newydd plant and at a second new NPP the company plans to build at Oldbury in Gloucestershire in western England.

On 12 October, the UK government released its 'Clean Growth Strategy', outlining the country' plans to achieve cleaner energy and transportation systems through the 2020s. Measures envisaged include a reduction in the carbon emissions from transport and heating, improved energy savings and a substantial construction programme of new clean energy power generation assets. The document was very well received by the country's nuclear industry, particularly on account of it mentioning nuclear generation as part of a future clean energy mix. The document should form the basis for a series of future energy, heating and transport policies.

The UK aims to open a geological disposal facility for spent nuclear fuel by 2040.

Table 1. Nuclear power reactors in the EU in 2017

Country	Reactors in operation (under construction)	Net capacity (MWe) (under construction)
Belgium	7	5 918
Bulgaria	2	1 926
Czech Republic	6	3 930
Germany(*)	8	10 799
Spain(**)	7	7 121
France	58 (1)	63 130 (1 650)
Hungary	4	1 889
Netherlands	1	482
Romania	2	1 300
Slovenia/Croatia (***)	1	688
Slovakia	4 (2)	1 814 (880)
Finland	4 (1)	2 769 (1 600)
Sweden (****)	8	8 622
United Kingdom	15	8 918
Total	127 (4)	119 306 (4 130)

(*) Germany — closure on 31 December 2017

(**) Spain — Garoña NPP — decision to keep it permanently off the grid.

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

(****) Permanent shutdown of Oskarshamn unit 1 power plant on 19 June 2017.

Source: World Nuclear Association (WNA).

As shown in Table 1, at the end of 2017 a total of 127 nuclear power reactors of different designs were in operation in the EU, producing 25.8 % of its electricity ([32]). As in 2016, four more were under construction.

In Spain and Finland, progress was made during 2017 on the new uranium mining projects, while all over the EU focus continued to be placed on diversifying sources of supply and addressing safety-related issues. France revised its previously national energy targets by deferring the date of capping nuclear energy's share in its energy mix, while waiting for other 'clean' sources to deliver. On nuclear plant construction, moderate progress was reported in France and Finland, while in Slovakia the project continued as planned and is on track for completion in 2018. Regulatory approval has been granted to extend the operational lifetime of one nuclear power reactor in Hungary and one in the Czech Republic. Decisions on operating lifetimes depend on current and forecast electricity market conditions and sometimes also on social and political factors. The Czech Republic has also started research into small modular reactors (SMRs). Work continued on the projects relating to the safe management of spent fuel and radioactive waste. Decisions were taken to permanently take or keep three reactors off the grid: in Germany, Spain and Sweden.

(32) Eurostat Energy Statistics, 2016

2. World market for nuclear fuels

This chapter presents a short overview of the main developments in 2017 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 WNA, as of 31 December 2017 there were 448 nuclear reactors operational in 31 countries, with a generation capacity of 391.5 GWe able to supply over 10 % of the world's electricity. World nuclear power generation slightly increased in 2017 compared to 2016, with the new generation capacity coming from the Asia-Pacific region.

Mulga Rock Uranium Project in Western Australia ©Vimy Resources Limited

The latest energy outlook issued by the US Department of Energy's Energy Information Administration (33) estimates that under the new policies scenario, global nuclear capacity will grow at an average annual rate of 1.6 % until 2040, led predominantly by countries outside the OECD. Nuclear power will be the third fastest growing source of electricity generation, after renewables and natural gas, from 2015 to 2040; the increase will be primarily due to substantial growth in China and to new reactor builds in India, the countries with the two highest forecast annual growth rates of nuclear generation. This growth is expected to offset declines in nuclear capacity in the United States, Japan and countries in Europe. However, the share of nuclear in total electricity generation worldwide will decrease from 11 % in 2016 to 10 % 2040, as the overall world electricity generation is expected to rise from 23.76 billion MWh in 2016 to 34 billion MWh in 2040.

In its recently projected vision on the future of electricity generation called 'Harmony' (34), the WNA believes that nuclear energy could contribute more to safe, reliable, clean and affordable electricity. As such, it envisages that in 2050 25 % of global electricity would be provided by nuclear energy. The Harmony programme provides the framework of action necessary for the nuclear industry to deliver its full value as a carbon free source of electricity.

According to various specialised publications, in 2017, four new nuclear reactors began operation, while construction started on another two, and three reactors were finally shut down. Currently, there are 57 nuclear reactors under construction, i.e. around 64 GW of new nuclear capacity, principally in China, but also in Russia, the United Arab Emirates, the United States, Korea, the EU and India. The United Arab Emirates is on track to becoming the first country to operate nuclear power reactors in the Arab world.

According to the International Energy Agency's latest world energy outlook (35), China has 36 nuclear power reactors in operation, 21 under construction and 31 more about to start construction. The reactors currently under construction belong to the more advanced Generation II and Generation III technology. China is also investing significant resources in the development of SMR technology. In the new policies scenario, nuclear generation increases five-fold, with generation growing to 1 100 TWh by 2040 (11 % of the total). China aims to adopt a standardised technology for long-term nuclear development and to develop the domestic technology needed to become self-sufficient in reactor design and construction, as well as in other stages of the fuel cycle. In 2017, it signed a memorandum of understanding with Saudi Arabia on bilateral cooperation in uranium and thorium resources. Under the agreement, China National Nuclear Corporation (CNNC) is to carry out exploration of nine potential areas in Saudi Arabia

(33) *International Energy Outlook 2017* (IEO2017).

(34) http://world-nuclear.org/harmony

(35) IEA, World Energy Outlook 2017, p. 602.

within the next 2 years. Also in 2017, CNNC signed a framework agreement with the Pakistan Atomic Energy Commission for technical cooperation in the exploration and development of uranium resources. Under the new agreement, China's uranium industry will fully employ its technological advantages, its nuclear research institutes and nuclear chemistry industry.

In Japan, only four of the country's 42 operable reactors were in operation at the end of 2017: Kyushu Electric Power Co.'s Sendai-1 and -2, each with a capacity of 890 MW, and Kansai Electric Power Co.'s Takahama-3 and -4, each with a capacity of 870 MW.

Three years after signing a civilian nuclear supply treaty, India received the first shipment of uranium from Australia in July 2017. The agreement signed between the Nuclear Power Corp. of India Ltd and Westinghouse for the engineering, procurement and construction of up to six units at the Kovvada site is being renegotiated following Westinghouse's reorganisation and its decision to no longer take a role in nuclear plant construction.

Rössing Uranium Mine in Namibia ©Euratom Supply Agency

While there are plans for a number of new reactors in the US, no more than two more new units will come online in the next 5 years. Westinghouse filed for chapter 11 bankruptcy reorganisation on 29 March 2017 after struggling to find cash to fund growing cost overruns at its two US nuclear plant projects. As a result, Southern Nuclear Operating Company took over project management to complete the two AP1000 reactors under construction at Vogtle, leaving Westinghouse simply as the vendor. Vogtle 3&4 would begin commercial operation in November 2021 and November 2022 respectively, under a new construction schedule. As for the other Westinghouse project, namely the two 1 200 MWe Westinghouse AP1000 reactors at Summer, South Carolina, their construction has been put on hold indefinitely.

In September 2017, the Nuclear Regulatory Commission (NRC) renewed licences for South Texas Project 1&2, extending the units' operation by 20 years to 2047 and 2048, respectively, which took to 89 the number of US power reactors to have had their licences renewed. The NRC is currently considering licence renewal applications for a further five units. Given that nuclear plants generate nearly 20 % of the nation's electricity overall and 63 % of its carbon-free electricity, even a modest increase in electricity demand would require significant new nuclear capacity by 2025 in addition to the two nuclear reactors currently under construction in order to maintain this share. If today's nuclear plants are retired after 60 years of operation, 22 GWe of new nuclear capacity would be needed by 2030, and 55 GWe by 2035 to maintain a 20 % nuclear share.

The Russian nuclear regulator has approved operation of Russia's first floating nuclear power plant, a modified version of the light-water PWRs used for more than 50 years by Russian nuclear icebreakers. Rosenergoatom plans to load fuel and proceed to first criticality by the end of November 2019. In October, Rosatom announced that it signed a cooperation agreement with Saudi Arabia's King Abdullah City for atomic and renewable energy. The agreement includes the potential for cooperation in the development of small and medium sized-reactors that could generate electricity and desalinate water. In November, Rosatom announced the signature of a Memorandum of Understanding with Brazil's Eletrobras and Eletronuclear to promote further cooperation in nuclear power, including the potential construction of a new NPP in Brazil. Also in 2017, Russia signed a nuclear cooperation agreement with Uzbekistan and began, via Rosatom, the construction of two nuclear reactors in Iran's southern province of Bushehr.

In April, Areva and Kazatomprom signed a major agreement to strengthen their long-standing cooperation in the uranium mining sector in Kazakhstan. The agreement presents new opportunities for further development and enhancement of effective operations of their KATCO joint venture (Areva — 51 %, Kazatomprom — 49 %) and gives it new long-term perspective with the development of the South Tortkuduk project, which will extend its production for the next two decades.

Natural uranium production

In 2017, global uranium production fell by 5 % as compared with 2016, totalling 59 236 tonnes of uranium. As in 2016, the top three uranium-producing countries were Kazakhstan, Canada and Australia.

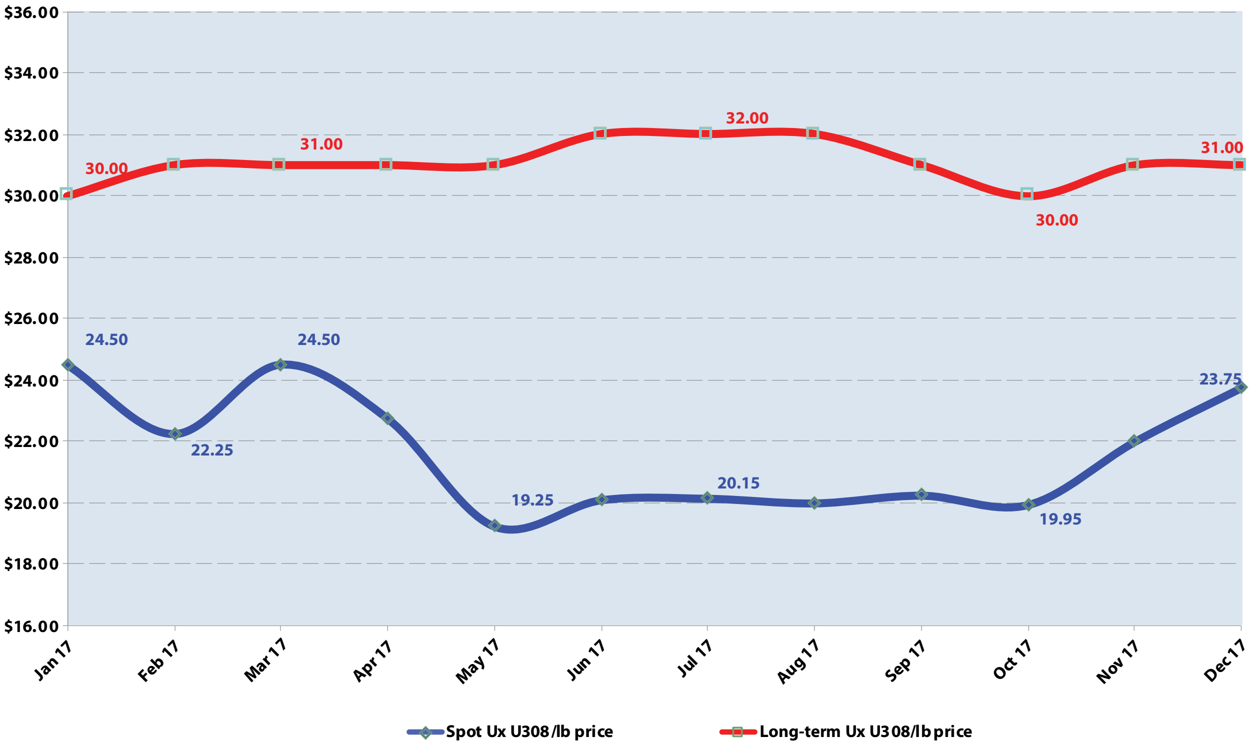
Kazakhstan remained the world's leading uranium producer in 2017, accounting for 40 % of total worldwide uranium output. The country's uranium production accounted for 23 463 tU in 2017, a decrease of 5 % on 2016 output, in line with the country's announced policy of downscaling production in the current market situation. Canada's production was estimated at around 13 263 tU in 2017, almost 7 % lower than the 2016 data. Australia's production was 15 % lower than in 2016, totalling 5 347 tU at the end of 2017.

Table 2. Natural uranium estimate production in 2017 (compared with 2016, in tonnes of uranium)

Region/country	Production 2017 (estimate)	Share in 2017 (%)	Production 2016 (final)	Share in 2016 (%)	Change 2017/2016 (%)
Kazakhstan	23 463	40	24 576	39	-5
Canada	13 116	22	14 039	23	-7
Australia	5 347	9	6 315	10	-15
Namibia	3 923	7	3 507	6	12
Niger	3 462	6	3 479	6	0
Russia	2 923	5	3 004	5	-3
Uzbekistan	2 423	4	2 404	4	1
China	1 896	3	1 616	3	17
United States	962	2	1 125	2	-15
Others	797	1	661	1	21
Ukraine	615	1	1 005	2	-39
South Africa	308	1	490	1	-37
Total	59 236	100	62 221	100	-5

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)



This market price information is provided with the permission of the Ux Consulting Company, LLC (UxC) — www.uxc.com.

The Ux spot price was more volatile during 2017 than in the previous year. It began the year at USD 24.50 per pound and gradually slipped down to below USD 20.00 per pound in May. It remained around this level until October, when the price rebounded to USD 22.00 per pound in November, and USD 23.75 per pound in December following announcements by big industry players that they would suspend or limit production in 2017.

The Ux long-term price was more resistant to these news and ranged between USD 30.00 and USD 32.00 per pound. It accounted for USD 31.00 per pound at the end of December.

Secondary sources of supply

In 2017, 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 weapons-grade uranium, reprocessed uranium (RepU) and plutonium recovered from spent fuel, re-enriched 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 deconverted, in France, Russia and the US, back to U_3O_8, 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. End-2017, 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

While uranium resources are extensive, the vast majority of them are not developed. They are quite widely distributed around the world, with Australia holding 23 % of the estimated resources, followed by Kazakhstan (14 %) and Canada (9 % of the identified resource base). According to the OECD/NEA and IAEA 'Red Book' — 'Uranium 2016, Resources, Production and Demand', the currently defined resource base could more than adequately meet the high scenario uranium demand estimates through 2035. However, timely investments are necessary for resources to be converted into ready-to-use natural uranium, as new projects are faced with various concerns like pricing pressures, geopolitical factors, technical challenges and environmental and regulatory considerations, which all increase the lead times required for their development. According to a study published by Trade Tech in October 2017, the decline in new uranium exploration and production worldwide due to ongoing low uranium prices raises the potential that nuclear utilities will face more challenges in buying material to meet their reactors' fuel needs in the next decade than they do today. The cumulative reduction in uranium reserves at 10 of the world's currently operating conventional and in situ uranium recovery facilities (including Cigar Lake in Canada, Inkai in Kazakhstan, Langer Heinrich in Namibia and SOMAIR in Niger) is estimated to represent 3 million lb U_3O_8 (around 1 120 tU) in 2018 and about 30 million lb U_3O_8 (around 11 200 tU) in 2025.

After producing its first drum of uranium on 30 December 2016, the Husab uranium mine in Namibia, the largest Chinese entity currently operating in Africa, reportedly produced over 1 000 tonnes of uranium oxide in 2017. Operated by China's state-owned China General Nuclear Power Corp, the third-largest uranium mine worldwide will continue to be optimised in 2018. When fully ramped up, the mine is estimated to produce around 7 000 t U_3O_8 annually. Also in 2017, Namibia's government agreed to lift a 10-year moratorium on new applications for exploration licences for uranium and nuclear fuel minerals in any area in the country.

Berkeley Energia Ltd reported further progress on the Salamanca uranium project in western Spain, with infrastructure work and the land acquisition process nearing completion. In August 2017, the company announced that it had signed an agreement with the sovereign wealth fund of the Sultanate of Oman for an investment of up to 120 million USD for a full financing of the Salamanca mine project. According to the terms of the agreement, the fund would become a long-term strategic investor in Berkeley, a potential offtake partner, and would also acquire the right to purchase 20 % of the mine's annual production of uranium concentrate (around 373 tU).

Recent forecasts from Ukraine's energy and coal industry ministry indicate that the country's output of uranium concentrates is expected to increase by 21.5 % year-on-year, as it aims to cover the entirety of its annual demand for yellow cake from domestic production. Energoatom plans to further increase production from the 1 221 tU expected in 2017 to about 2 480 tU/year in 2019 and 2020 once the Novokostiantynivsk deposit, which contains the largest reserves of uranium in Ukraine, and which is one of the 10 largest uranium deposits in the world, has reached its scheduled capacity.

In February, the US NRC announced it had issued an operating licence to AUC LLC for the Reno Creek in situ recovery uranium facility in Campbell County, Wyoming.

In September, BHP Billiton reported that two major milestones had been achieved as regards the underground operations expansion and heap leach research and development trials at its Olympic Dam mine in South Australia. This is part of the currently expanding underground mining operations that the company is conducting into the southern mining area at the mine site, with a view to reaching untapped copper and uranium resources.

In October, Terrafame Ltd, operator of the Sotkamo nickel mine in Finland, reported that it would apply to Finland's government for a permit to recover uranium as a by-product of nickel/zinc mining. Once it has received the permit, the company estimates that it could begin uranium recovery operations towards the end of 2019.

Russia's Rosatom has decided to postpone development of the Mkuju River uranium project in Tanzania for a period of at least 3 years, until uranium demand starts to increase again.

Areva NewCo reported its intention to cut uranium production and staffing levels at its SOMAIR and COMINAK uranium mines in Niger. It is expected that the annual production of the open-pit SOMAIR mine will be reduced to 1 700 tU in 2018 from 2 100 tU in 2017.

Starting January 2018, Cameco Corp. will suspend uranium production at its McArthur River conventional uranium mine and Key Lake Mill for 10 months as a result of continued uranium price weakness.

In January 2017, NAC Kazatomprom announced its decision to decrease 2017 production by 10 % in response to declining uranium prices. At the end of the year, in line with its efforts to better align its uranium output with demand, the company publicly confirmed its intention to reduce planned uranium production by 20 %. Kazatomprom has informed its major customers of the cut-back decision and has ensured that future contractual delivery obligations will not be impacted. China will remain the main buyer of Kazakh uranium, accounting for over 50 % of the country's total uranium exports. Kazakh production is expected to stabilise at its current level and the country is expected to remain the biggest uranium producer worldwide.

Conversion

Conversion plants are operating commercially in the US, Canada, France, Russia and China. The main new plant is Areva's Comurhex II, operating between two sites in France, at Malvési and Tricastin, and expected to reach its nameplate capacity in 2022. China's 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.

In 2017, world nameplate primary conversion capacity was estimated at around 57 500 tU, with the actual conversion production assumed at 45 740 tU. Part of the supply continued to be provided by secondary conversion sources. Secondary supply of equivalent conversion services includes UF_6 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.

Table 3. Commercial UF_6 conversion facilities

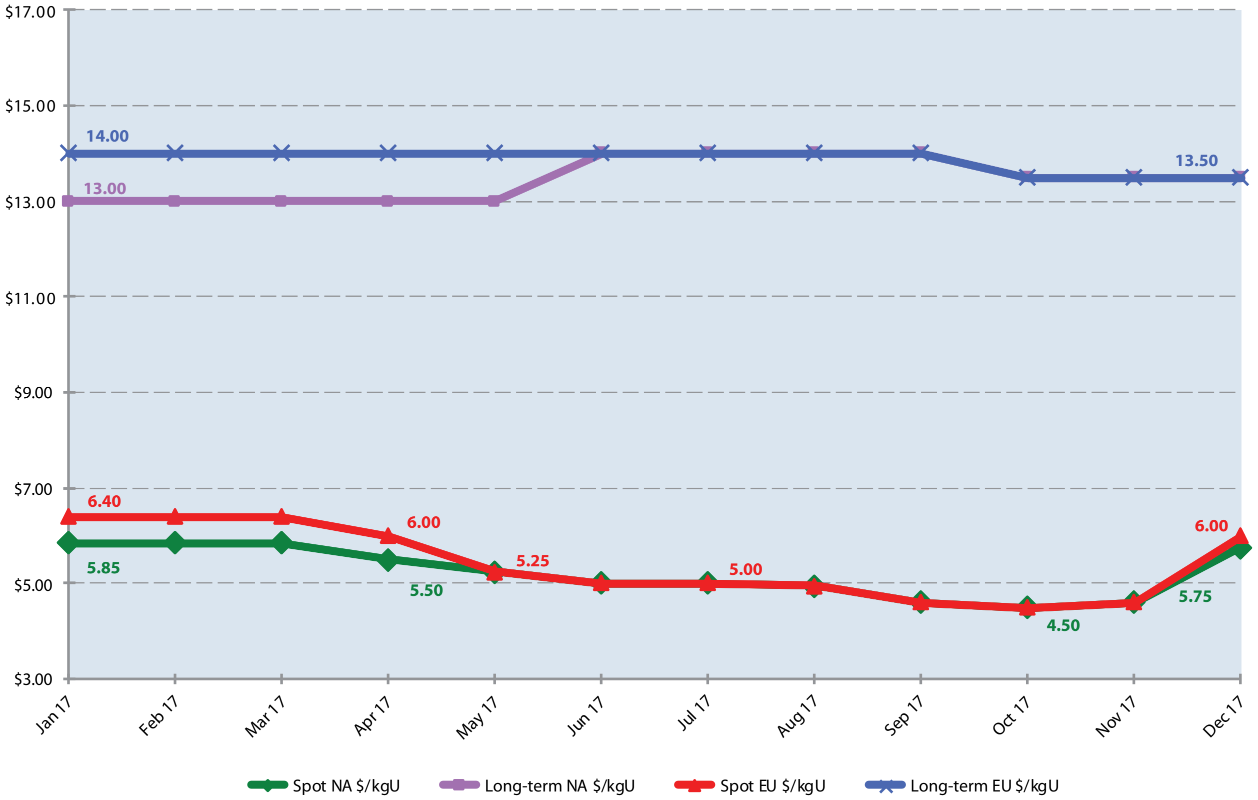
Company	Nameplate capacity in 2017 (tU as UF_6)	Share of global capacity (%)
Atomenergoprom* (Russia)	**18 000**	**31.3**
Comurhex (France)	**15 000**	**26.0**
Cameco (Canada)	**12 500**	**21.7**
ConverDyn (United States)	**7 000**	**12.2**
CNNC (China)	**5 000**	**8.7**
Total nameplate capacity	**57 500**	**100**

Because of rounding, totals may not add up.

Source: WNA, The Nuclear Fuel Report — Global Scenarios for Demand and Supply Availability 2017-2035.

* Nameplate capacity unknown, but assumed based on announced production targets.

Figure 2. Uranium conversion price trends (in USD)



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European and North American Ux spot conversion prices were stable during the first quarter of 2017 before starting to drop steadily from USD 6.40 per kgU and USD 5.85 per kgU respectively to USD 4.50 per kgU in October. In November, prices slightly rebounded and finished the year at USD 6.00 per kgU in the EU and USD 5.75 per kgU in North America.

The European Ux long-term conversion prices were stable from January until the end of September and amounted to USD 14.00 per kgU. The North American Ux long-term conversion prices accounted for USD 13.00 per kgU until May before increasing to 14.00 per kgU. In October both indices dropped to USD 13.00 per kgU and did not change until the end of the year.

In February, the Canadian Nuclear Safety Commission announced it had renewed the operating licence of Cameco's Port Hope uranium conversion facility in Ontario, Canada for a 10-year term until February 2027.

On 28 December, Areva NC announced that it formally ceased all UF_6 production activities at the Comurhex I conversion plant at its Tricastin site in southern France as part of its transition to the new Comurhex II conversion facilities. During more than 50 years, the Comurhex I facilities contributed to the safe supply of conversion services in Europe, with unique reliability performances. The Comurhex II plant at the Malvési site is already in operation, since 2016. The Comurhex II plant at the Tricastin site is set to go into first commercial operations before end of 2018, after a series of testing and equipment qualification. The targeted total output of 15.0 million kgU of UF_6 shall be reached by 2022 for these new Comurhex II facilities.

No western converter has announced plans to expand current conversion capacity, which could result in a potential risk for the balance between UF_6 demand and supply. Although Cameco and KazAtomProm had announced in 2016 their intention to look into the potential opening of a conversion refinery in Kazakhstan, the current weak market conditions provided no reason for the joint venture to move forward. In theory, according to the WNA, ConverDyn has the ability to expand production capabilities at the Metropolis site, but so far there is no market incentive for that. In November, Honeywell even confirmed that due to the drastic decrease in demand in recent years and the reduced demand outlook to 2020, the company would temporarily suspend UF_6 production at the Metropolis Works uranium conversion facility in Illinois. The company will maintain minimal operations at the plant to support a future restart, should business conditions improve.

Enrichment

In 2017, 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 over the 2017-2030 period, albeit at a rhythm 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. Projected primary supplier capacities will be more than sufficient to meet enrichment demand at least through 2025. 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. Due to the current oversupply imbalance in the market, enrichers have slowed down the pace of any planned expansions of existing capacity and even resorted to reducing existing capacity by not replacing centrifuges reaching the end of their lifetimes. China is one of the few enrichers expanding its capacity considerably, 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 2017 capacity

Company	Nameplate capacity (tSW)	Share of global capacity (%)
TVEL/Tenex (Russia)	28 416	45.0
Urenco (UK/Germany/Netherlands/United States)	18 758	32.3
AREVA-GBII (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.

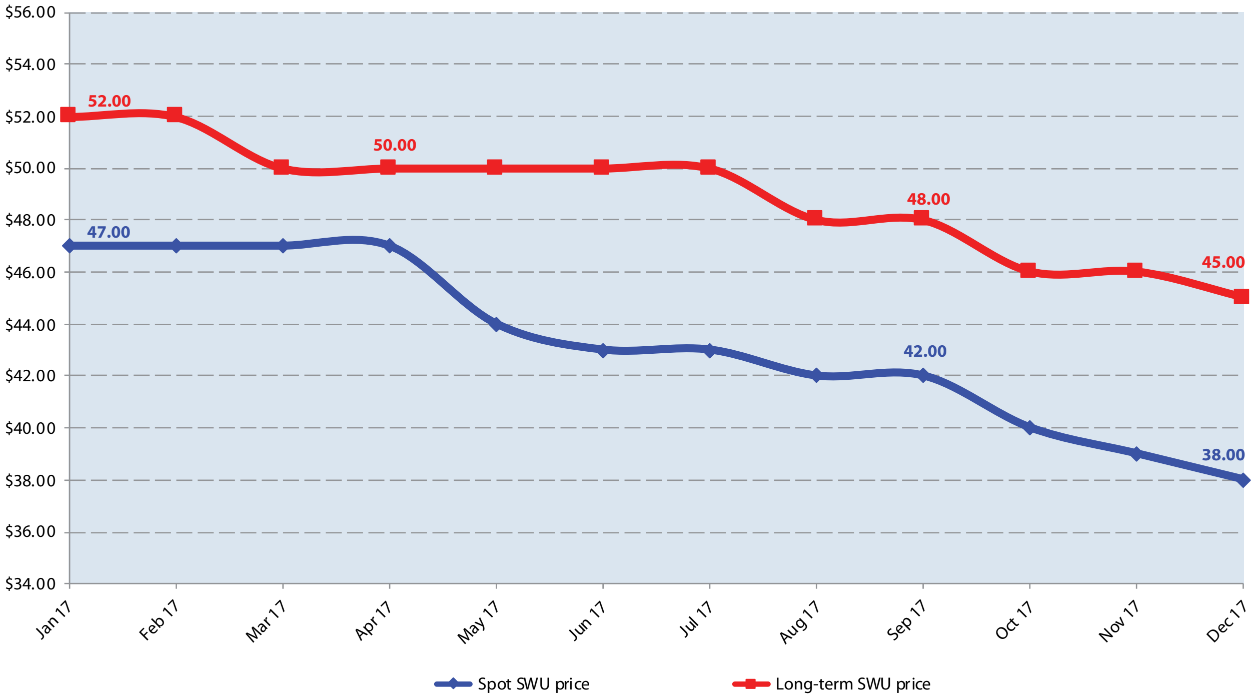
Silex Systems Ltd reported in December progress on the restructuring of GE-Hitachi (GEH) Global Laser Enrichment LLC (GLE). As such, Silex is considering acquiring all of GEH's 76 % interest in GLE, subject to the satisfactory finalisation of transaction documentation, and conditional on obtaining the necessary US government approvals. It is estimated that a binding agreement might be reached in the first quarter of 2018. The SILEX technology commercialisation project conducted by GLE and Silex continues to make steady progress at the Wilmington, North Carolina test loop facility and at Silex's Lucas Heights laser development facility in Sydney, Australia.

Mid-2017, Japan's Nuclear Regulation Authority confirmed that it had approved a review report according to which Rokkasho, Japan's only licensed uranium enrichment facility, which is operated by Japan Nuclear Fuel Ltd, meets the latest national regulatory safety standards.

Centrus Energy announced that in the first half of 2017 it had signed several new LEU sales contracts with deliveries through 2025, for a total value of USD 70 million.

On 29 August, the IAEA, the government of Kazakhstan, and the Nuclear Threat Initiative reported the official opening of the LEU fuel bank in the Ulba Metallurgical Plant in the eastern Kazakh city of Ust-Kamenogorsk. Fully funded by voluntary contributions from IAEA Member States and other donors (including EUR 25 million by the European Commission/EU), the fuel bank will be owned and operated by the IAEA and is the first of its kind not to be under the control of any individual country. With a capacity of up to 90 tonnes of LEU, the fuel bank is designed to provide nuclear power countries a secure supply of uranium fuel for peaceful purposes, while not imposing on them the need to incur costs and global proliferation risks relating to the construction of new enrichment facilities. The procurement process for the LEU is ongoing and the material should be in the bank in 2018.

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



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The spot Ux SWU price fell continuously during 2017, similarly to the previous year. It began the year at USD 47.00 per SWU and held that level through to the end of April, then slipped to USD 44.00 per SWU at the end of May before dropping throughout the rest of the year, ending up at USD 38.00 per SWU.

Similarly, the Ux long-term SWU price also fell during the year. It began the year at USD 52.00 per SWU and remained at the same level until the end of February. The price slipped to USD 50.00 per SWU at the end of March before again remaining at the same level until the end of July. Additional declines were noted in August, October and December. As a result, the long-term price ended the year at USD 45.00 per SWU, a yearly decrease of almost 13.5 %, setting a new reported historical low.

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

In March, Japan Nuclear Fuel Ltd and Mitsubishi Heavy Industries Ltd confirmed that they were finalising with Areva the terms of their investment in NewCo, corresponding to a 5 % stake each.

In April, following the finalisation of a draft report on upgraded safety measures, Japan's Nuclear Regulation Authority granted Global Nuclear Fuel-Japan the final approval to operate its BWR fuel fabrication plant. As no BWRs are currently operational in Japan, fuel fabrication at the Global Nuclear Fuel-Japan is only occurring at a minimal level to maintain the technology in working order.

Rosatom officials announced in May that the company planned to begin installing already in 2017 equipment at a new mixed uranium nitride-plutonium fuel fabrication and re-fabrication facility at the Siberian Chemical Combine. Using material recovered through reprocessing of spent fuel, the facility will fabricate nuclear fuel for Rosatom's first 300-MW BREST-300 lead-cooled fast reactor as part of the Proryv project, which involves the development of a new generation of Russian fast reactors. In June, TVEL Fuel Company confirmed its intention to deliver in 2019 a test batch of its TVS-K fuel to a US NPP. Production of the new fuel design, targeted for export to the US and Swedish nuclear fuel markets, is already under way.

Ukraine's nuclear regulator announced in July that fuel fabricated by Westinghouse at its Swedish facility had passed state safety-related nuclear material testing and would be loaded into Zaporozhe reactors (1 and 4). The units, each 1 000 MW, will thus have mixed cores containing TVEL and Westinghouse fuel. Westinghouse fuel is already used in the 1 000 MW units at South Ukraine (2 and 3) and Zaporozhe (3 and 5).

In October, following a 26-month effort, Westinghouse Electric Company and its eight European consortium partners successfully completed an EU-funded project, known as 'European Supply of Safe Nuclear Fuel' (ESSANUF), intended to diversify the nuclear fuel supply to VVER-440 reactors in Europe. The consortium developed a conceptual fuel design and determined how the manufacturing and supply chain can be re-established to build and ship VVER-440 fuel assemblies, similar to what was done by Westinghouse and ENUSA to the Loviisa Nuclear Power Plant in Finland in 2001-2007. In addition to fuel design, the consortium also set up and verified the associated methods and methodology to be applied for the licensing and use of a new fuel design in the VVER-440 reactors.

Fuel fabricators are developing new 'accident-tolerant' fuel, based on different technical solutions. Westinghouse announced in June that it had formally launched its accident-tolerant nuclear fuel solution, EnCore Fuel, which is designed to offer design-basis-altering safety, greater uranium efficiency and huge estimated economic benefits to its customers. The first lead test assemblies containing the first phase of its accident-tolerant fuel will be loaded at Exelon's Byron NPP in the spring of 2019. As for Areva's new accident-tolerant fuel, test assemblies containing rods of the fuel will be loaded at Southern Nuclear Operating Co.'s Vogtle-2 NPP in Georgia, US, during a spring 2019 refuelling outage.

Lightbridge Corp. and Areva NP in North America announced the signature of a binding agreement on the development, manufacturing and commercialisation of Lightbridge's advanced metallic fuel technology. A joint venture with equal participation of the two companies is expected to be launched in the first quarter of 2018 and should develop Lightbridge's metallic fuel designs as well as demonstrate, license, fabricate and sell the fuel and other advanced nuclear fuel intellectual property of both companies. Lightbridge's metallic uranium fuel would be enriched to almost 20 % U-235 and could allow existing and new LWRs to operate at higher power levels.

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. The recovery of uranium and plutonium through reprocessing of spent fuel is currently 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.

According to WNA, some 90 000 tonnes of used fuel from commercial power reactors (of 290 000 tonnes discharged) have been reprocessed to date. Further use of the recovered material requires dedicated conversion, enrichment and fabrication facilities. Reprocessed uranium (as ERU fuel assemblies) and plutonium (in MOX fuel) still played a role in meeting the demand for nuclear fuel in 2017, as a replacement for fresh LEU in the supply mix of European, Russian and Japanese utilities, by displacing approximately 1 900 tU. The savings are expected to increase and reach about 2 400 tU equivalent in 2020 and up to 5 700 tU equivalent in 2030, mainly due to a substantial recycling programme in Russia. To date, there are significant stockpiles of plutonium worldwide, and countries like the US, 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 over the 2017-2035 period MOX and ERU will contribute around 2 million SWU per year to total SWU supply worldwide ([36]).

Areva has completed the clean-up and dismantling of facilities at the former MOX fuel fabrication plant at Cadarache in southern France, home to around 20 nuclear installations, including the international ITER fusion demonstration project. The plant, which had the capacity to produce 42 tonnes of MOX fuel annually, manufactured its last MOX fuel rods in July 2003. Over its 40 years of operation, the plant recycled more than 50 tonnes of plutonium.

In February, New Areva signed a framework agreement for industrial and commercial cooperation with CNNC on fuel cycle activities and supporting negotiations on a reprocessing plant.

Early September, URENCO reported that its Tails Management Facility at Capenhurst in the UK should be finally commissioned in 2018. The facility, designed to deconvert depleted UF_6 into the more chemically stable uranium oxide for long-term storage, had previously been expected to enter service in 2017 but had faced construction delays.

(36) 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.

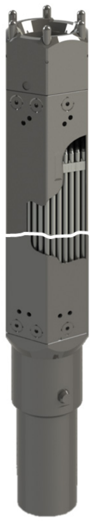
At the end of 2017, there were 127 commercial nuclear power reactors operating in the EU, located in 14 Member States and managed by 18 nuclear utilities. There were four reactors under construction in France, Slovakia and Finland. According to the latest available data published by the European Commission, the gross electricity generation from nuclear plants within the EU-28 Member States in 2016 was 839.7 TWh, which accounted for 25.8 % of total EU-28 production(37).

Dukovany NPP spent fuel cask closing ©CEZ

(37) Eurostat Energy Statistics, 2016.

Fuel loaded into reactors

In 2017, 2 232 tU of fresh fuel was loaded into commercial reactors in the EU-28. It was produced by using 16 084 tU of natural uranium and 460 tU of reprocessed uranium as feed, enriched with 12 101 tSW. The quantity of fresh fuel loaded increased by 7 % (i.e. 145 tU more than in 2016). In 2017, the fuel loaded into EU reactors had an average enrichment assay of 3.92 %, 80 % falling between 3.20 % and 4.64 %. The average tails assay was 0.23 %, more than 90 % falling between 0.20 % and 0.26 %.



VVER-440 fuel concept design ©ESSANUF Consortium

In 2017, MOX fuel was used in a number of reactors in France, Germany and the Netherlands. MOX fuel loaded into NPPs in the EU contained 10 696 kg Pu in 2017, a 19 % increase over the 9 012 kg Pu used in 2016. Use of MOX resulted in estimated savings of 993 tU and 691 tSW (see Annex 5).

The total amount of natural uranium included in fuel loaded into EU reactors in 2017, including natural uranium feed, reprocessed uranium and savings from MOX fuel, was 17 537 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.

Table 5. Natural uranium equivalent included in fuel loaded by source in 2017

Source	Quantities (tU)	Share (%)
Uranium originating outside the EU([1])	16 084	91.7
Indigenous sources ([2])	1 453	8.3
Total annual requirements	17 537	100

([1]) includes small quantities of material saved through underfeeding

([2]) reprocessed uranium and savings from usage of MOX fuel

Future reactor requirements (2018-2037)

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.

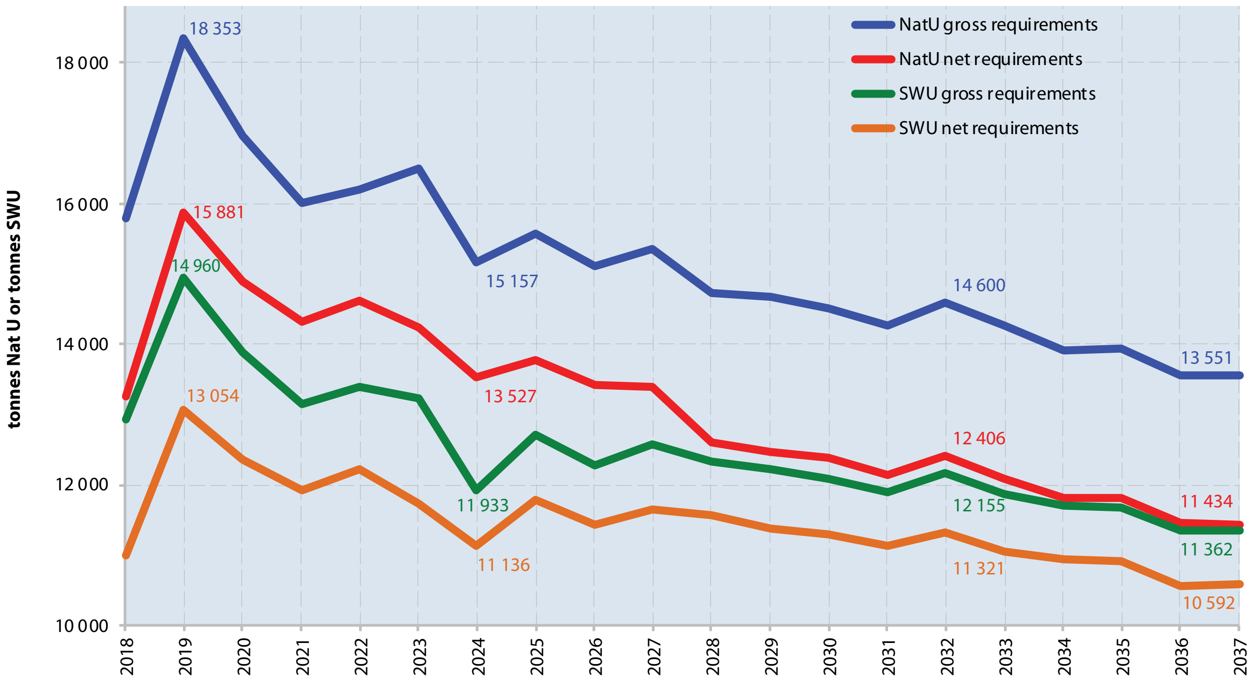
Natural uranium — average reactor requirements		
2018-2027	16 103 tU/year (gross)	14 137 tU/year (net)
2028-2037	14 202 tU/year (gross)	12 062 tU/year (net)

Enrichment services — average reactor requirements		
2018-2027	13 102 tSW/year (gross)	11 830 tSW/year (net)
2028-2037	11 864 tSW/year (gross)	11 075 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 increased for the second. For 2018-2027, forecasts of average gross requirements for natural uranium have stayed at the same level, whereas they have fallen by 1 % (84 tSW) for separative work. For 2028-2037, the average gross demand for natural uranium has increased by 3 % (425 tU) and for enrichment services by 4 % (487 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 2017, ESA processed a total of 123 natural uranium contracts and amendments to contracts, of which 70 (57 %) were newly concluded contracts. Of 65 new purchase/sale contracts, 38 % 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)

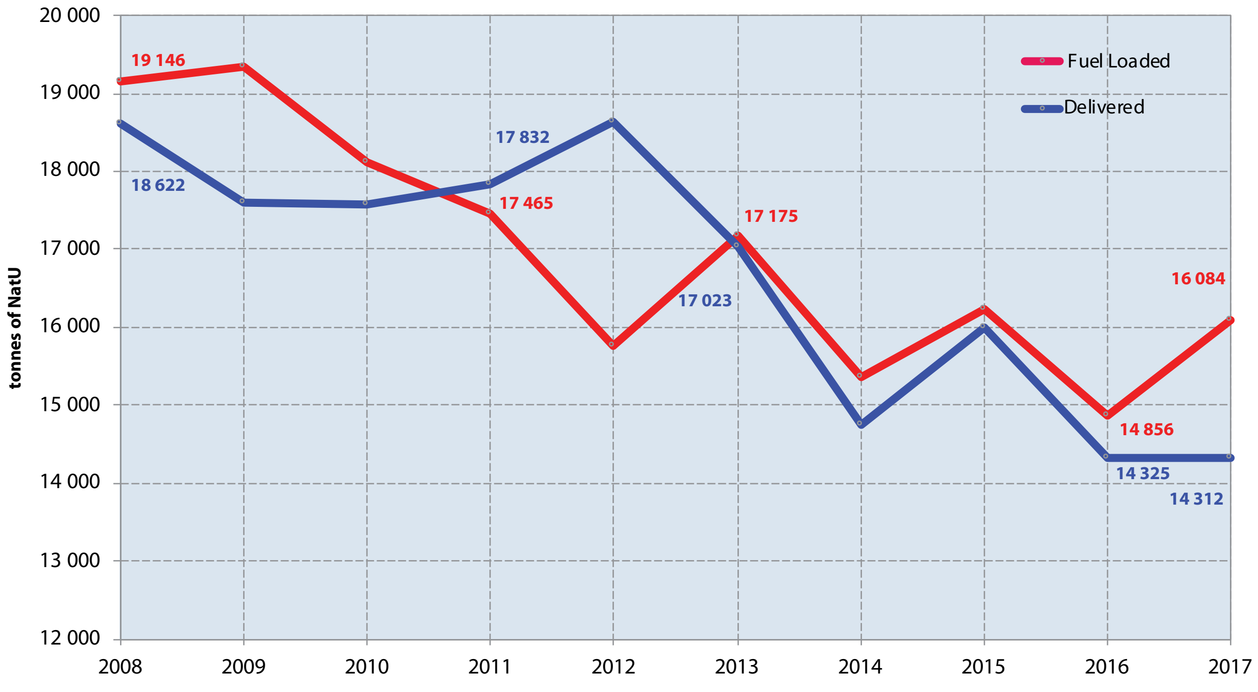
Type of contract	Number of contracts concluded in 2017	Number of contracts concluded in 2016
Purchase/sale by EU utilities/users	**25**	**17**
— multiannual ([1])	8	12
— spot ([1])	17	5
Purchase/sale by EU intermediaries/producers	**40**	**40**
— multiannual	13	8
— spot	27	32
Exchanges and loans ([2])	**5**	**10**
Amendments	**53**	**40**
TOTAL ([3])	**123**	**107**

([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 2017, excluding research reactors. The natural uranium equivalent contained in enriched uranium purchases, when stated, is also taken into account.

In 2017, demand for natural uranium in the EU represented approximately one quarter of global uranium requirements. EU utilities purchased a total of 14 312 tU in 141 deliveries under long-term and spot contracts, which is approximately the same level as in 2016. As in previous years, supplies under long-term contracts constituted the main source for meeting demand in the EU. Deliveries of natural uranium to EU utilities under long-term contracts accounted for 13 769 tU (of which 12 995 tU with reported prices) or 96 % of total deliveries, whereas the remaining 4 % (544 tU) was purchased under spot contracts. On average, the quantity of natural uranium delivered was 115 tU per delivery under long-term contracts and 42 tU per delivery under spot contracts.

Natural uranium contained in the fuel loaded into reactors in 2017 totalled 16 084 tU. 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 1980-2017).

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 2017 stood at 1.13, which was 2 % 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 long-term 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 2017 was calculated as:	
EUR 55.16/kgU contained in U_3O_8	**38 % down from EUR 88.56/kgU in 2016**
USD 23.97/lb U_3O_8	**36 % down from USD 37.71/lb U_3O_8 in 2016**

2. ESA long-term U_3O_8 price: the weighted average of U_3O_8 prices paid by EU utilities for uranium delivered under multiannual contracts in 2017 was calculated as:	
EUR 80.55/kgU contained in U_3O_8	**7 % down from EUR 86.62/kgU in 2016**
USD 35.00/lb U_3O_8	**5 % down from USD 36.88/lb U_3O_8 in 2016**

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 2017, was calculated as:	
EUR 80.50/kgU contained in U_3O_8	**8 % down from EUR 87.11/kgU in 2016**
USD 34.98/lb U_3O_8	**6 % down from USD 37.09/lb U_3O_8 in 2016**

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 2017, the ESA U_3O_8 spot price was EUR 55.16/kgU (or USD 23.97/lb U_3O_8). Prices varied widely, 80 % falling within the range of EUR 44.83 to EUR 66.37/kgU (USD 19.48 to USD 28.84/lb U_3O_8).

The ESA long-term U_3O_8 price was EUR 80.55/kgU U_3O_8 (USD 35.00/lb U_3O_8). Long-term prices paid varied widely, with approximately 65 % (assuming a normal distribution) falling within the range of EUR 53.18 to EUR 109.26/kgU (USD 35.29 to USD 47.48/lb U_3O_8). Usually, long-term 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 long-term 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 long-term contracts. On average, the multiannual contracts which led to deliveries in 2017 were signed 10 years earlier.

The ESA long-term U_3O_8 price paid for uranium originating in the Commonwealth of Independent States (CIS - Russia, Kazakhstan and Uzbekistan) was 16 % lower than the price for uranium of non-CIS origin.

The ESA MAC-3 multiannual U_3O_8 price was EUR 80.50/kgU U_3O_8 (USD 34.98/lb U_3O_8). The data were spread across a wide range, with approximately 70 % of prices reported as falling between EUR 53.91 and EUR 106.16/kgU (USD 23.43 to USD 46.13/lb U_3O_8). The ESA MAC-3 index takes into account only long-term contracts signed recently (2015-2017) or older long-term 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 8 % higher than the price for uranium of non-CIS origin.

Figures 6a and 6b show the ESA average prices for natural uranium since 2008. The corresponding data are presented in Annex 3.

Figure 6a. Average prices for natural uranium delivered under spot and multiannual contracts, 2008-2017 (EUR/kgU)

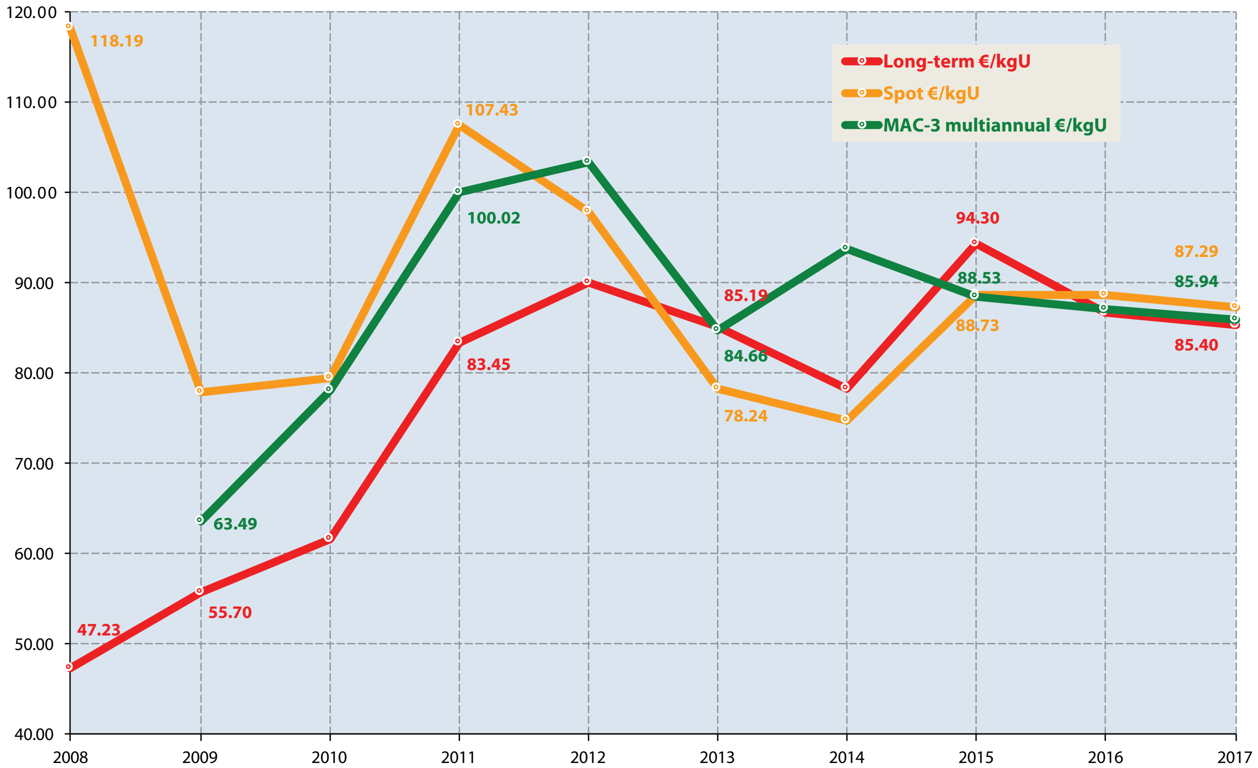
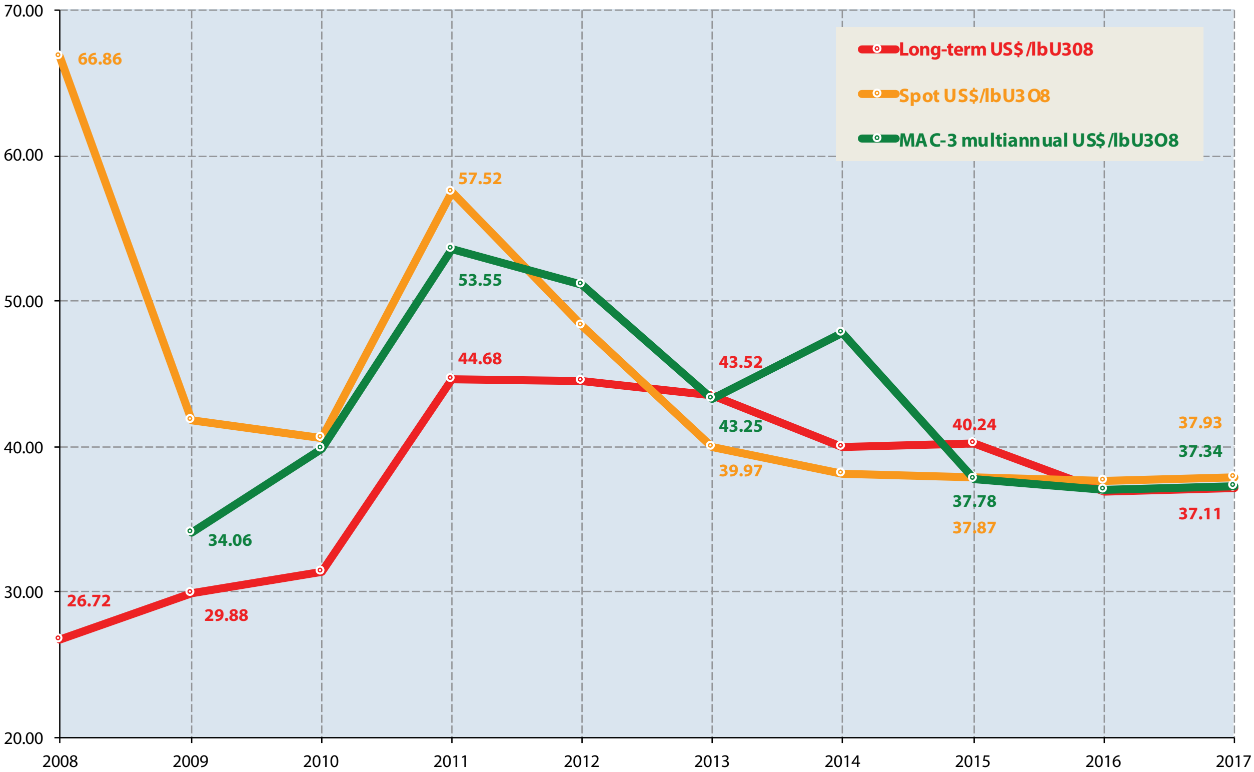


Figure 6b. Average prices for natural uranium delivered under spot and multiannual contracts, 2008-2017 (USD/lb U_3O_8)



Origins

In 2017, natural uranium supplies to the EU continued to come from diverse sources. The origins of natural uranium supplied to EU utilities have remained unchanged since 2016, although there have been some changes in market share.

Table 7. Origins of uranium delivered to EU utilities in 2017 (tU)

Origin	Quantity	Share (%)	Change in quantities 2017/2016 (%)
Canada	4 099	28.6	39.2
Russia	2 192	15.3	-20.7
Niger	2 151	15.0	-31.8
Australia	2 091	14.6	10.3
Kazakhstan	2 064	14.4	-8.7
Namibia	923	6.4	83.1
Uzbekistan	348	2.4	201.9
United States	193	1.3	54.2
Re-enriched tails	171	1.2	-19.2
Other (1)	80	0.6	-38.5
Total	14 312	100.0	-

Because of rounding, totals may not add up.

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

Canada and Russia were the top two countries delivering natural uranium to the EU in 2017, providing 43.9 % of the total. Of this, uranium originating in Canada accounted for 28.6 % of total deliveries, with that originating in Russia representing 15.3 % (including purchases of natural uranium contained in EUP). In third place, uranium mined in Niger amounted to

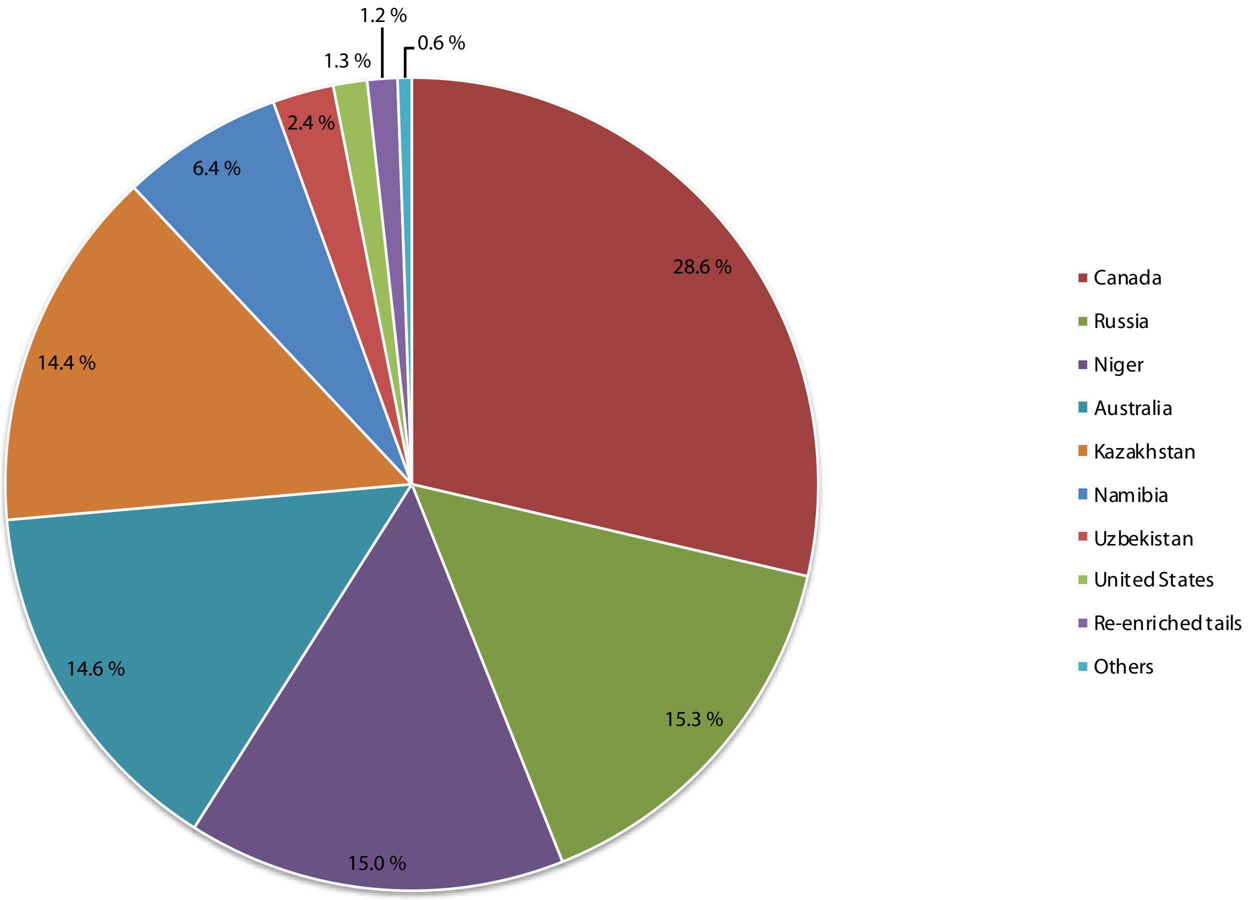
15 % of the total. Australia and Kazakhstan accounted for 14.6 % and 14.4 % respectively in 2017. The five big producing countries together provided 88 % of all natural uranium supplied to the EU.

Natural uranium produced in CIS countries accounted for 4 776 tU, or 33.4 % of all natural uranium delivered to EU utilities, a 10.8 % decrease from the year before.

Deliveries of uranium from Africa fell by 15.9 % to 3 074 tU, compared to 3 656 tU in 2016. Uranium mined in Africa originated in two countries, Niger and Namibia, with Niger representing 70 % of African-origin deliveries in 2017.

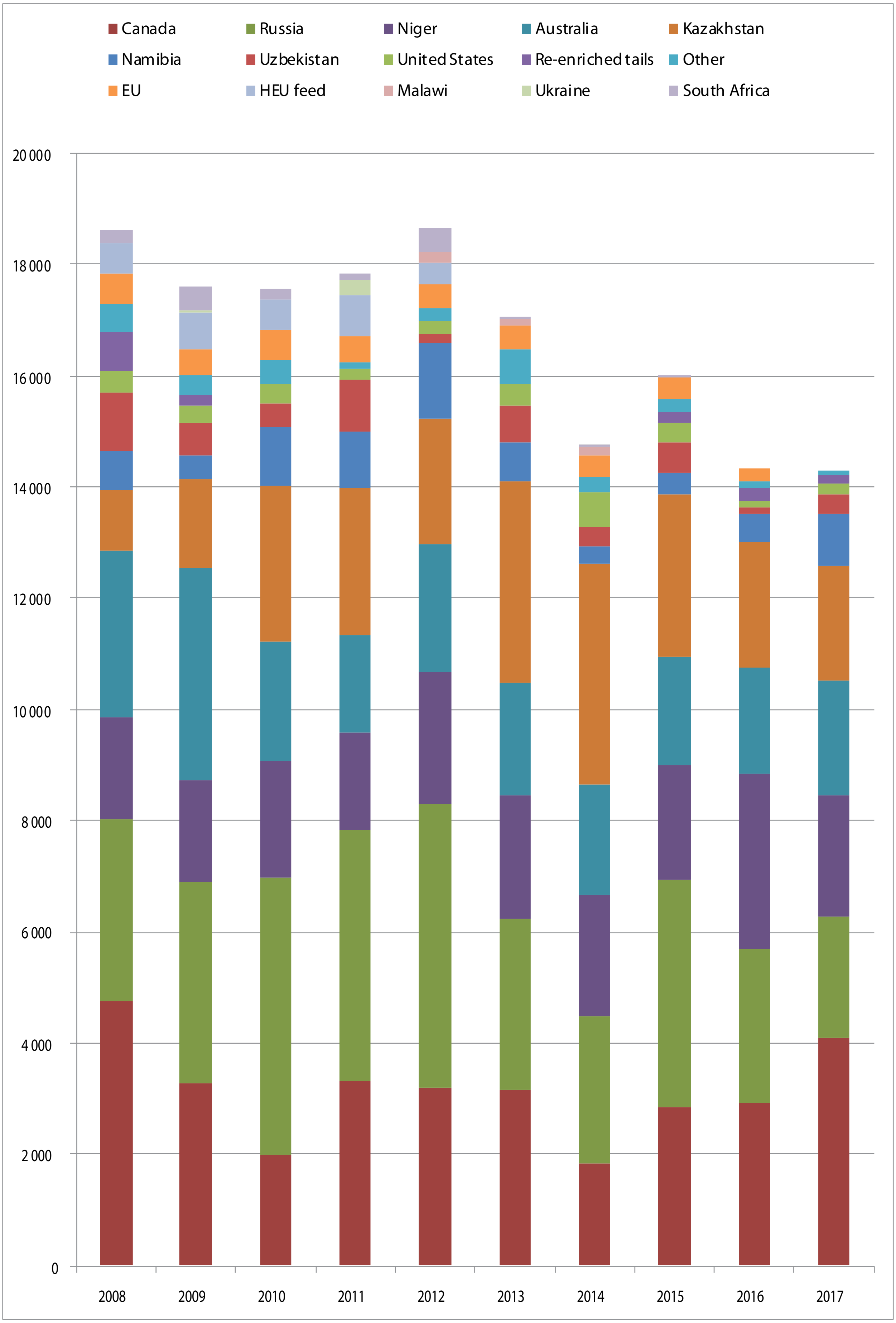
There were no deliveries of uranium originating in Europe to EU utilities as the mines in the Czech Republic and Romania had closed.

Figure 7. Origins of uranium delivered to EU utilities in 2017 (% share)



Because of rounding, totals may not add up.

Figure 8. Purchases of natural uranium by EU utilities, by origin, 2008-2017 (tU)



Conversion services

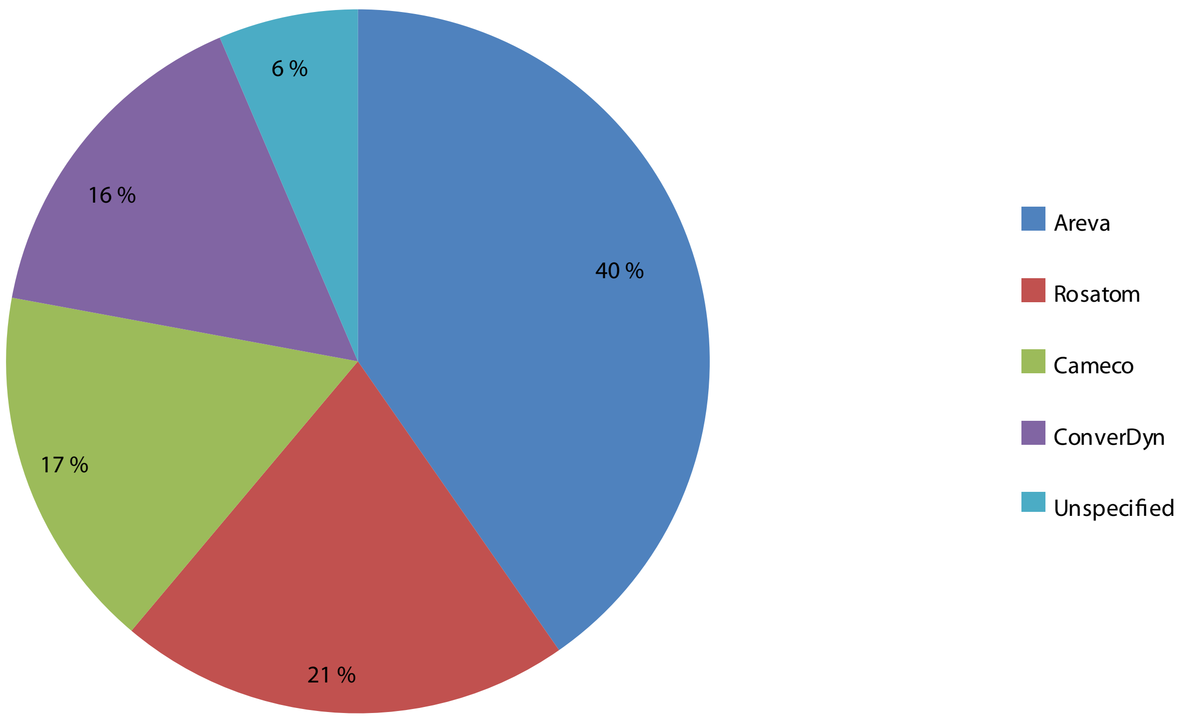
In 2017, 40 % of EU requirements of conversion services were met by AREVA / Comurhex, followed by Rosatom (21 %), Cameco (17 %) and ConverDyn (16 %).

Out of the total quantity of conversion services provided, 8 458 tU were supplied under separate conversion contracts, which accounted for 66 % of all conversion service deliveries to EU utilities. The remaining 34 %, or 4 358 tU, were delivered under contracts other than conversion contracts (purchases of natural UF_6, EUP, bundled contracts for fuel assemblies).

Table 8. Provision of conversion services to EU utilities

Converter	Quantity in 2017 (tU)	Share in 2017 (%)	Quantity in 2016 (tU)	Share in 2016 (%)	Change in quantities 2017/2016 (%)
Areva (EU)	5 166	40	5 490	39	-6
Rosatom (Russia)	2 668	21	3 848	27	-44
Cameco (Canada)	2 149	17	2 265	16	-5
ConverDyn (US)	2 010	16	2 031	14	-1
Unspecified	823	6	636	4	23
Total	12 816	100	14 269	100	-11

Figure 9. Provision of conversion services to EU utilities by provider, 2017 (% share)



Special fissile materials

Conclusion of contracts

Table 9 shows the aggregate number of contracts, notifications and amendments ([38]) relating to special fissile materials (enrichment services, enriched uranium and plutonium) handled in 2016 and 2017 in accordance with ESA's procedures.

Deliveries of low-enriched uranium

In 2017, the enrichment services (separative work) provided to EU utilities totalled 10862 tSW, delivered in 1731 tonnes of low-enriched uranium (tLEU), which contained the equivalent of 13540 tonnes of natural uranium feed. In 2017, enrichment service deliveries to EU utilities increased by 1 % compared to 2016, with NPP operators opting for an average enrichment assay of 4.12 % and an average tails assay of 0.23 %.

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

Type of contract	Number of contracts concluded/notifications acknowledged in 2017	Number of contracts concluded/notifications acknowledged in 2016
A. Special fissile materials		
New contracts	**31**	**41**
Purchase (by an EU utility/user)	8	15
Sale (by an EU utility/user)	3	5
Purchase/sale (between two EU utilities/end users)	4	3
Purchase/sale (intermediaries)	12	14
Exchanges	4	4
Loans	0	0
Contract amendments	**29**	**19**
TOTAL ([1])	**60**	**60**
B. Enrichment notifications ([2])		
New notifications	**11**	**11**
Notifications of amendments	**23**	**20**
TOTAL	**34**	**31**

([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 2017 (tSW)	Share in 2017 (%)	Quantities in 2016 (tSW)	Share in 2016 (%)	Change in quantities 2017/2016 (%)
AREVA/GBII and Urenco (EU)	7 691	71	7 579	70	1
Tenex/TVEL (Russia)	2 524	23	2 966	28	-15
Russian blended ([1])	447	4	119	1	275
Centrus (formerly USEC) (US)	200	2	110	1	81
TOTAL ([2])	10 862	100	10 775	100	1

([1]) Including enriched reprocessed uranium.

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

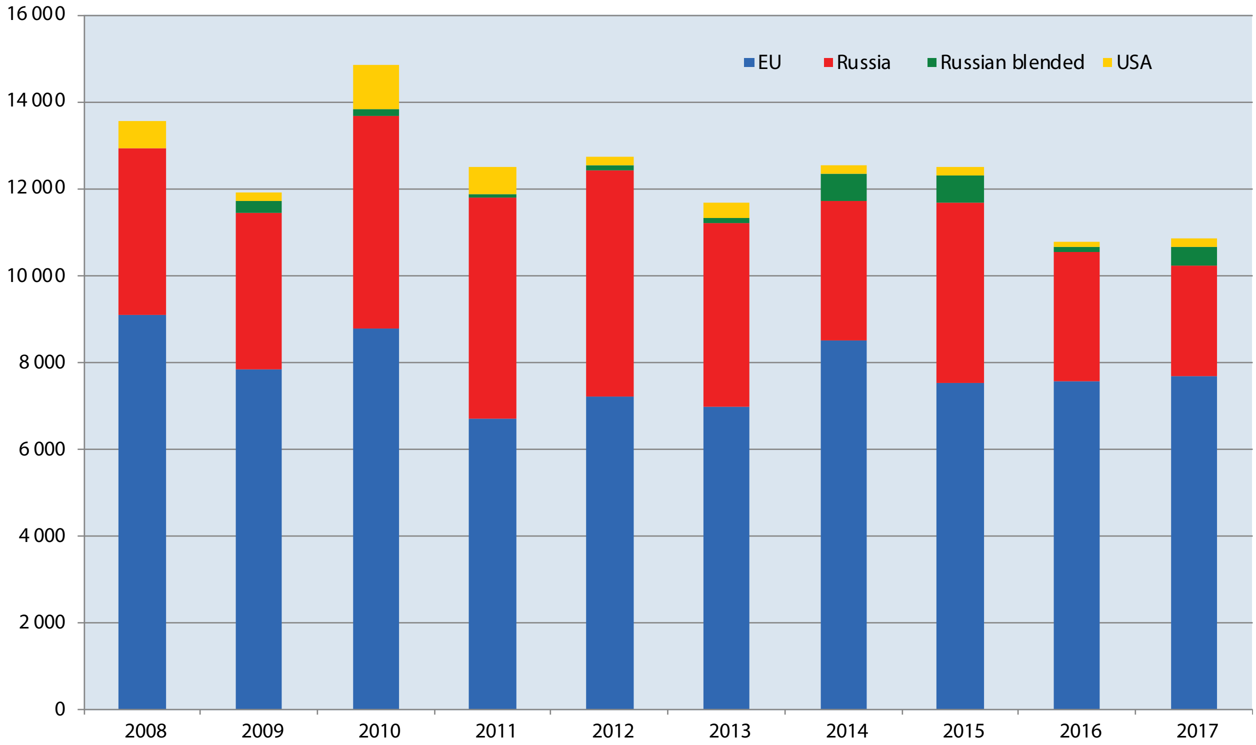
(38) The aggregate number of amendments includes all the amendments to existing contracts processed by ESA, including technical amendments that do not necessarily lead to substantial changes in the terms of existing agreements.

As regards the providers of enrichment services, 71 % of EU requirements were met by the two European enrichers (AREVA-GBII and Urenco), totalling 7 691 tSW, an increase of 1 percentage point in year-on-year comparison.

Deliveries of separative work from Russia (Tenex and TVEL) to EU utilities under purchasing contracts totalled 2 524 tSW, which accounts for 23 % of total deliveries, a 15 % decrease 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), and covered less than 4 % of total EU requirements. Russian enrichment services provided under other contracts accounted for 19 % of total requirements.

Enrichment services provided by Centrus increased by 81 % compared to 2016, totalling 200 tSW and accounting for 2 % of total enrichment services supplied to EU utilities.

Figure 10. Supply of enrichment to EU utilities by provider, 2008-2017 (tSW)



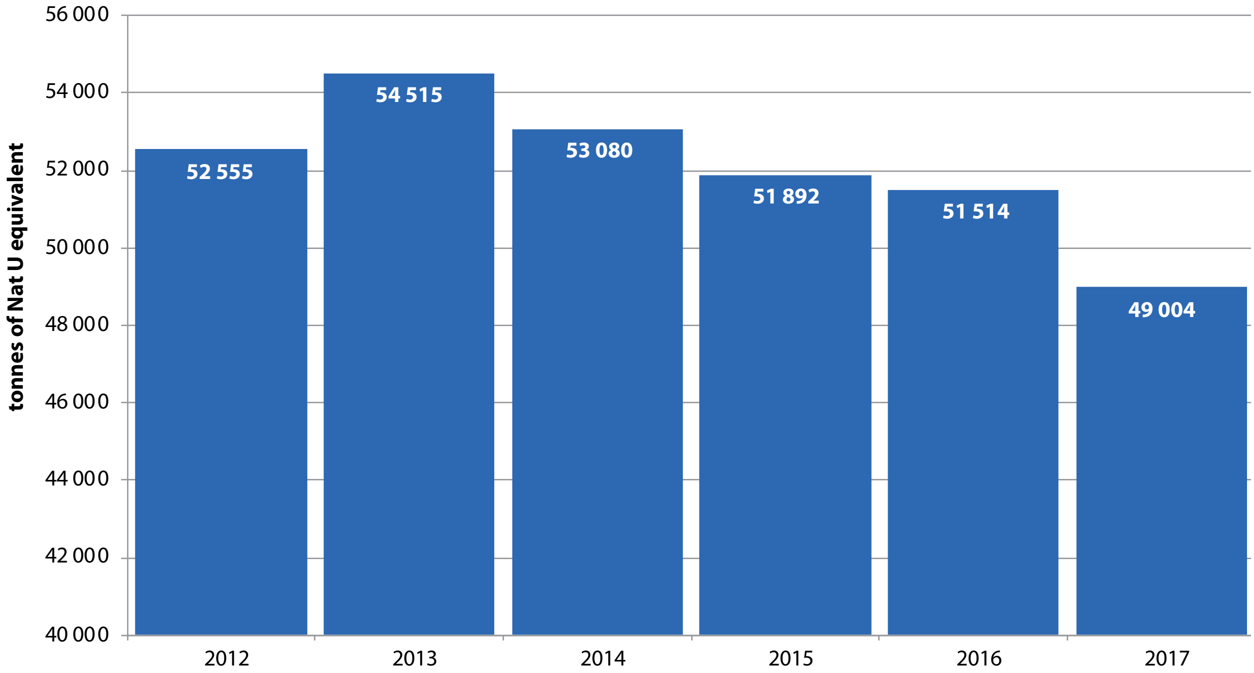
Plutonium and MOX fuel

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 10 696 kg in 2017, a 19 % increase over the 9 012 kg used in 2016.

Inventories

At the end of 2017, the natural uranium equivalent in inventories owned by EU utilities totalled 49 004 tU, a decrease of 5 % from the end of 2016 and a decrease of 7 % compared to the level at the end of 2012. 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, 2012-2017 (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 16 000 tU per year), uranium inventories can fuel EU utilities' nuclear power reactors for three years on average. However, the average conceals a wide range, although most utilities keep a sufficient quantity of inventories for at least one reload.

Future contractual coverage rate

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.

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

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 2018-2027 are estimated at approximately 14 100 tU and 11 800 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.

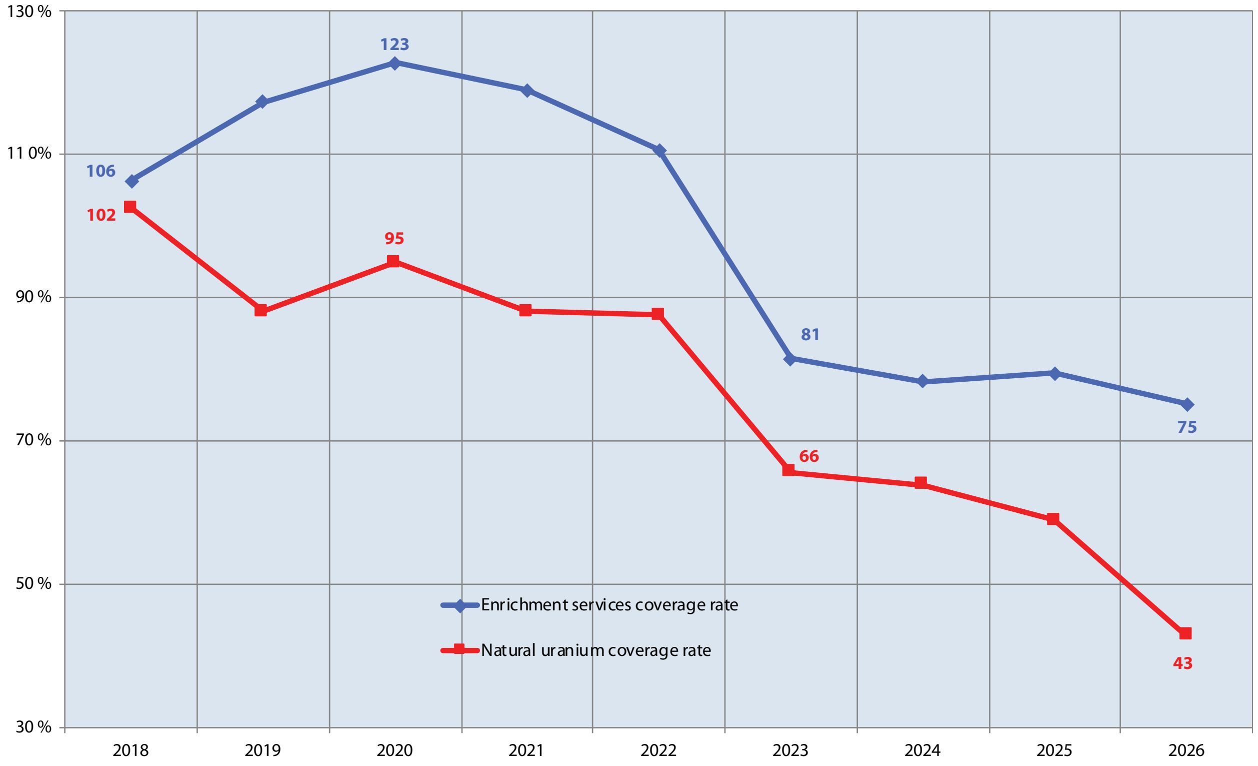
Quantitative analysis shows that EU utilities are well covered (about 90 % of their estimated net reactor requirements) until 2020, in terms of both natural uranium and enrichment services, under existing contracts.

For natural uranium, supply is well secured from 2018 to 2022, with a contractual coverage rate of over 100 % in 2018 and between 87 % and 95 % between 2019 and 2022. In the long term, the uranium coverage rate drops below 70 % after 2022 and ends at 43 % in 2026.

Enrichment service supply is well secured until 2022, with a contractual coverage rate of over 100 %. It will stand at 81 % in 2023 and will remain above 70 % until 2026.

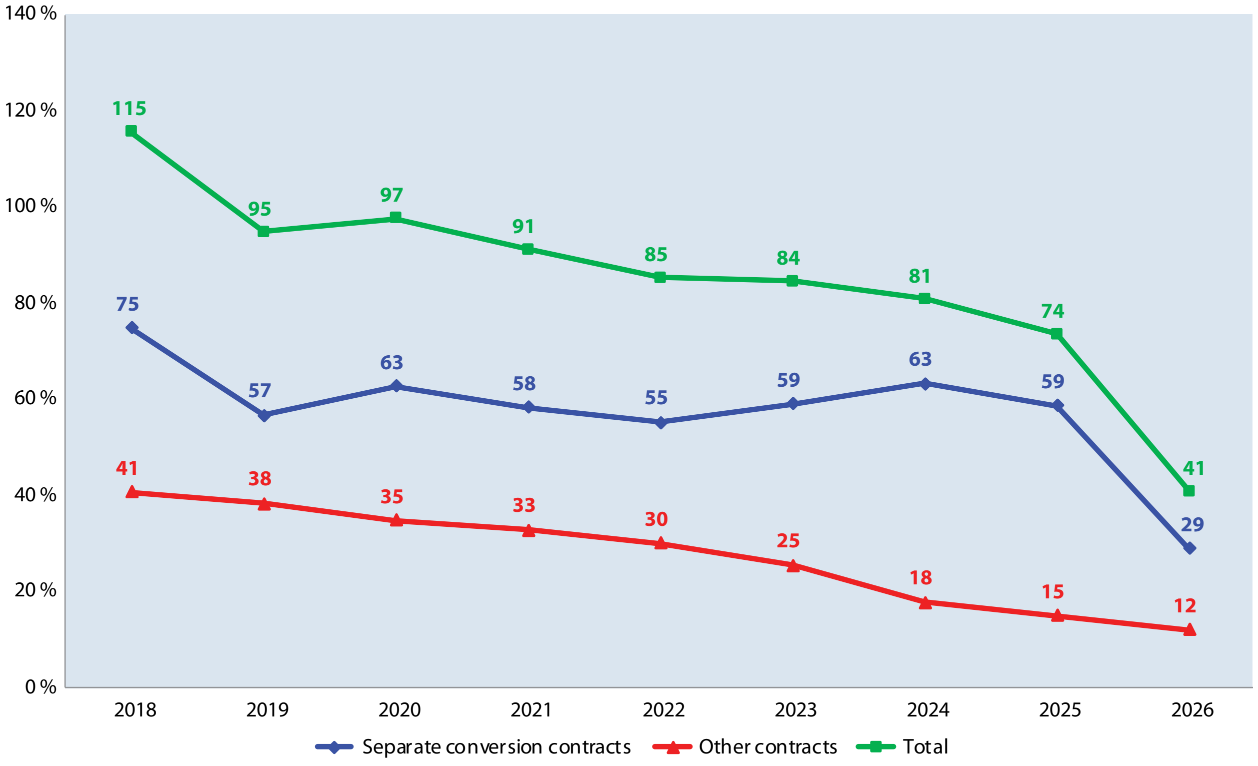
In general, EU utilities' reactor requirements for both natural uranium and enrichment services are sufficiently covered in the short and medium term.

Figure 12. Coverage rate for natural uranium and enrichment services, 2018-2026 (%)



Quantitative analysis of conversion services shows that between 91 % and 115 % of EU utilities' net reactor requirements until 2021 are covered under existing contracts. Supply is well secured until 2025 with a contractual coverage rate accounting for more than 70 %, while it drops to 41 % in 2026.

Figure 13. Coverage rate for conversion services, 2018-2026 (%)



ESA findings, recommendations and diversification policy

In accordance with its statutory mission, ESA has continued to monitor the nuclear market with a view to identifying 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 third-country supplier, 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 long-term contracts from diverse sources of supply. In line with this recommendation, deliveries of natural uranium to the EU under long-term contracts accounted for 96 % of total deliveries in 2017. As regards mining origin, the relative shares of individual producer countries changed in comparison with the previous year, with Canada, Russia, Niger, Australia and Kazakhstan together providing 88 % of the natural uranium delivered to the EU. In 2017, deliveries of uranium from Australia and North America increased by 10 % and 40 % respectively. In contrast, deliveries of uranium from the CIS and Africa decreased by 11 % and 16 % respectively. There were no deliveries of uranium mined in the EU. 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.

As regards the diversification of sources of supply of enriched uranium to EU utilities, 71 % of enrichment services were provided by the two European enrichment companies, AREVA-GBII and Urenco. The remaining services were provided mostly by Russia's Tenex/TVEL (23 %), and by the American company USEC (2 %), which currently operates as an intermediary, following its reorganisation in 2013.

In 2017, total deliveries of enrichment services increased by 1 % compared to 2016. The two European enrichers increased their relative share in the EU market by one percentage point (from 70 to 71 %) even if deliveries of enrichment services provided by them remained at almost the same level as in the previous year. This is explained by the fact that deliveries of SWUs of Russian origin fell by 15 %, and their relative share in the EU market by 5 %. Out of the 23 % of SWUs of Russian origin, contracts 'grandfathered' under Article 105 of the Euratom Treaty accounted for less than 4 % of total deliveries.

ESA welcomes the use of reprocessed uranium, either by blending it with HEU to produce power reactor-grade fuel or by having it re-enriched, on the basis that such practices increase security of supply. Furthermore, blending reprocessed uranium with HEU of military origin is conducive to nuclear disarmament and the non-proliferation of nuclear materials. ESA therefore takes account of these positive aspects of reprocessed fuel use when implementing its diversification policy. HEU blended with reprocessed uranium and re-enriched reprocessed uranium fuel accounted for the equivalent of approximately 4 % of the total enrichment services provided in 2017. This was higher than in the previous year, when it amounted to 1 % of the total enrichment services provided.

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 2017 totalled 49 004 t of natural uranium equivalent, which could fuel EU utilities' nuclear power reactors for an average of three 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 2017, 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

For many years already, the global nuclear industry has been trying to adapt to the lower demand environment following the Fukushima Daiichi accident. Although some reactors in Japan have started operating again, legal and political challenges remain, and at the same time plans to reduce the use of nuclear energy in South Korea and Taiwan have made the Asian growth story less compelling. China and India continue to invest in nuclear generation, but in the United States some reactors have closed for economic reasons.

Fuel assembly handling Tihange NPP ©Synatom

The uranium market situation continues to favour buyers, but increasingly the financial health of suppliers is becoming an issue for long-term security of supply. In 2017, major suppliers such as Areva, Westinghouse and Paladin had to undergo restructuring. Further announcements were made by Cameco and Kazatomprom about reductions in natural uranium production.

In Europe, uranium mines were closed in the Czech Republic and Romania, while new projects are underway in Spain and Finland. The outlook for new reactors in Europe is highly uncertain: several countries have plans to build new NPPs, but the EU Member State with the biggest nuclear fleet, France, is looking at reducing the share of nuclear in its energy mix. An additional element of uncertainty in the European context is the planned exit of the United Kingdom from the EU, including the Euratom Community.

In any case, for those countries and companies not phasing out nuclear or considering building new reactors, long-term security of supply remains of the utmost importance, regardless of market conditions. Fuel buyers must plan for future supplies over a very long period of time, which may include different business and commodity price cycles.

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 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 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.

ESA must make use of 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 their supply sources or to implement remedial measures.

Supply side — assessment of the global situation

For several years, primary production of natural uranium was increasing but it seems now to have plateaued following recent announcements of reductions in the US, Canada and Kazakhstan. However, the cutbacks in production are still not sufficient to have a significant impact on prices. Although primary production does not cover worldwide reactor requirements, there is clear over-supply on the market because of secondary sources (HEU down-blending, RepU and Pu use in MOX fuel, inventory draw-down, tails re-enrichment), and in particular 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.

Olkiluoto 3 NPP ©TVO

In the short term, further production cuts appear necessary to support prices and guarantee that exploration and future mine development work can continue in view of the next upcycle. 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 worldwide 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 nevertheless critical step in the fuel cycle. The decision of ConverDyn in late 2017 to idle its Metropolis facility in the US effectively reduces the number of active conversion suppliers on the world market from four to three. Although this facility is being kept ready for a restart, this event underlines the fragile nature of a limited supply chain. At current SWU prices, a reduction in the global enrichment capacity can no longer be excluded.

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.

The same concern applies to fuel fabrication, where world capacity is also more than sufficient. Within this segment, the lack of alternative suppliers of VVER fuel remains an issue in many countries operating VVER reactors.

Transport also remains an issue which could lead to a short-term supply disruption. Cross-border transport of radioactive materials has become increasingly complex and time-consuming owing to 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. Many companies are therefore trying to develop alternative shipping routes or adopt different means of shipment for specific deliveries. 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 have been launched 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. 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. Currently, 8 % of the nuclear material used in fuel loaded into EU reactors comes from indigenous sources in various forms (see Table 5).

For other parts of the fuel cycle (conversion, enrichment, fuel fabrication and spent fuel reprocessing), EU industry can cover most or all of EU utilities' needs. 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 as regards security of supply. The main challenge is to ensure the continued viability 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.

The capacity to produce fuel and components for VVER reactors in the EU is an important aspect which still needs attention. Production capacity has been re-established for VVER-1000 fuel produced in Sweden and used in Ukraine, and consideration is being given to re-establishing such capacity for VVER-440 fuel manufacturing in the EU as well, as indicated in Chapter 2.

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 or four 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, the Czech Republic, 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 36 % 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, in view of licensing and testing requirements.

Future contractual coverage rate

As detailed in Chapter 3, and taking into account EU utilities' contractual coverage 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 two years of operation, in different forms (natural or enriched uranium, fabricated fuel assemblies), and all utilities are covered for at least one year. 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.

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.

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 2017 (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 long-term 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.

As regards fuel fabrication, there has been no change in the 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.

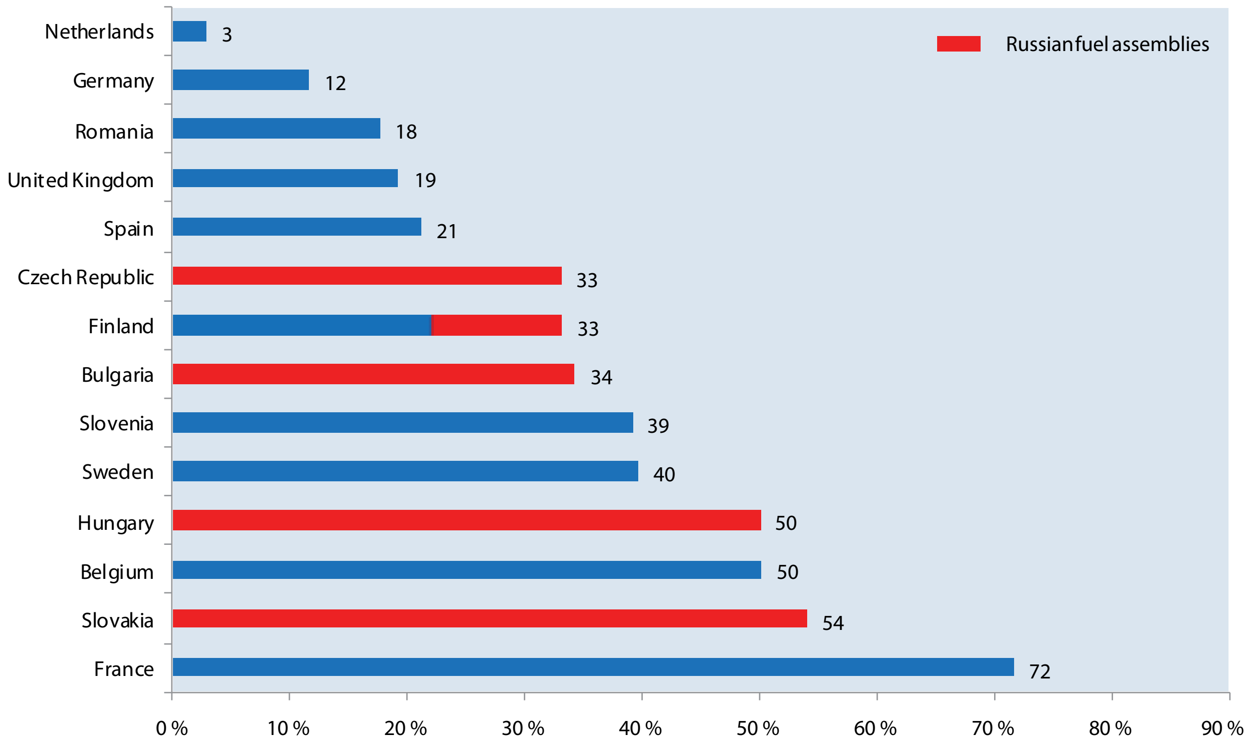
From a security-of-supply viewpoint, there should always be at least two alternative suppliers for each stage of the fuel cycle. The second best option is to have a diversified portfolio up to the fabrication stage and maintain a strategic stock of fabricated fuel. Ideally, all utilities should hold 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 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. Likewise, VVER-1000 reactor operators in the EU are taking steps towards the licensing of alternative fuel. These efforts are further encouraged. Further cooperation at the level of operators and between national regulators of countries operating VVER reactors would be useful to expedite the licensing process for alternative fuel.

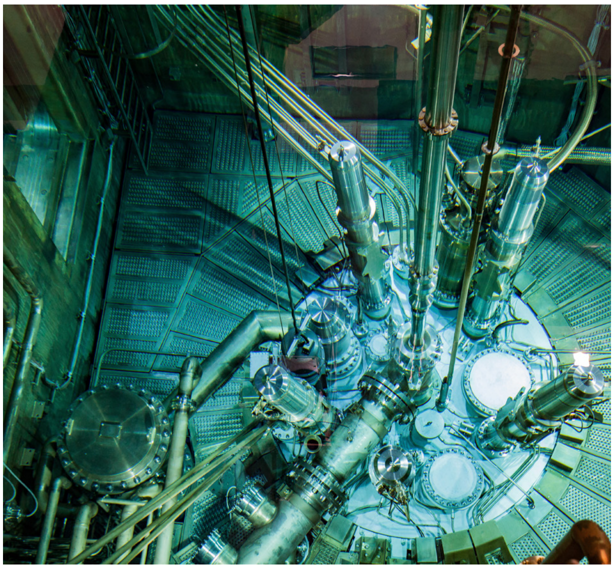
Although the above ESA recommendations are targeted mainly at utilities, it is clear that for long-term security of supply, EU producers should also maintain a skilled workforce, further develop their technology and continue to invest in their production facilities to the extent possible under the prevailing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

Figure 14. Nuclear power share of total electricity production in the EU, 2017 (%)



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 supply disruption can have negative and sometimes life-threatening consequences for patients.



FRM II reactor ©TUM

ESA involvement

In the light of the Council Conclusions 'Towards the secure supply of radioisotopes for medical use in the EU' dated 2010 ([39]) and 2012 ([40]), ESA's observatory role was widened in 2013 to cover aspects of the supply of medical radioisotopes in the EU. In 2017 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 ([41]).

In addition, in 2017, ESA was involved in the preparatory work led by the European Commission's Directorate-General for Energy for the development in 2018 of the Samira project. A large part of this agenda focuses on the supply of medical radioisotopes.

Follow-up work to the Memorandum of Understanding between ESA and the US DoE-NNSA on the exchange of HEU continued in 2017. ESA continued to focus on security of fuel supply for research reactors, both for scientific research and for the production of medical radioisotopes, covering the period after the future conversion of such reactors to operate with LEU 19.75 %.

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 institutions and national governments in devising strategies and the policies to implement them. It is composed of representatives of the EU institutions and various industry stakeholders, most of which are grouped within the AIPES (Association of Imaging Producers and Equipment Suppliers) ([42]). In 2017, the Observatory held two plenary meetings, in Luxembourg in March and in Munich in October. Until mid-2017 the Observatory carried out its work through four working groups: 1 — Global reactor scheduling and Mo-99 supply

(39) http://ec.europa.eu/euratom/docs/118234.pdf.
(40) http://ec.europa.eu/euratom/docs/2012_council_radioisotopes.pdf.
(41) http://ec.europa.eu/euratom/observatory_radioisotopes.html.
(42) http://www.aipes-eeig.org.

monitoring, 2 — Full-cost recovery mechanisms, 3 — Management of HEU-LEU conversion and target production and 4 — Capacity and infrastructure development. Mid-2017 the Observatory introduced some changes to its working methods. It was decided that the plenary meetings would continue to take place twice a year but the permanent working groups would be closed, as they have completed their mandates and achieved their objectives. The activities of the Working Group on reactor scheduling coordination have been taken over by the AIPES Security of Supply Working Group, reporting regularly to the Observatory. In addition, it was proposed that ad hoc meetings or working groups can be organised to deal with specific questions, should this be necessary.

Jules Horowitz Reactor in France ©CEA

At the March meeting, the topics on the Observatory agenda were research reactor scheduling, status of HEU-LEU conversion of the EU production facilities, uranium targets transport issues, updates from the AIPES, OECD/NEA and EMA (European Medicines Agency) and the status of the European Commission projects on the supply of medical radioisotopes. At the October meeting, in addition to the above-mentioned subjects, the Group discussed the EU/Euratom financial instruments supporting research reactor infrastructure and the first draft of an updated European Research Reactor Position Paper on Sustainable Mo-99 Production in Europe.

Reactor scheduling and Mo-99 supply monitoring

The AIPES Security of Supply Working Group ensures effective coordination of reactor maintenance schedules to avoid and mitigate Mo-99 supply disruptions. The emergency response team (ERT) created within this working group and composed of representatives of research reactors, Mo-99 processors and Mo-99/Tc-99 m generator manufacturers, monitors production and supply issues on a week-by-week basis. This continuous monitoring makes it possible to identify potential Mo-99 shortages and to draw up mitigation action plans involving all stakeholders. In November 2017, the ERT was activated to focus on the outage of the NTP processing facility in South Africa (which lasted until February 2018). As supply was limited during this period, shortages occurred in some regions, therefore, detailed Mo-99 production monitoring was performed and all possible mitigation actions were undertaken. A joint communication team set up in 2014 to communicate promptly with government representatives in the event of supply interruptions was activated during the NTP outage to provide regular information updates to various stakeholder groups, including the EU Council's Working Party on Atomic Questions (43) and the Health Security Committee (44).

Full-cost recovery mechanisms

One of the key principles of the policy approach of the OECD/NEA High-level Group on the Security of Supply of Medical Radioisotopes (HLG-MR) is that all Mo-99/Tc-99 m supply chain participants 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 sustainability of the Mo-99 supply. In 2016 the Dutch Presidency of the Council of the European Union addressed this subject in a position paper submitted to the energy ministers at the Energy Council meeting of June 2016 (45). The Presidency was of the view that the underlying cause of previous supply disruptions was and still is the unsustainable economic structure of the medical radioisotopes production chain. To ensure a secure supply of medical radioisotopes in the medium and long term, a system of FCR must be implemented. In this context, the Presidency note suggested various measures that should be undertaken at EU level. This has resulted in a research project initiated in 2017 by the European Commission's Joint Research Centre. The project, which aims to contribute to a sustainable and resilient supply of medical radioisotopes in the EU, will, among other aspects, investigate the medical radioisotope reimbursement systems in the EU Member States.

HEU/LEU (enriched to 19.75 %) supply for target production and research reactor fuel

It remains very important to scrutinise the potential risks to the security of supply of HEU and LEU (enriched to 19.75 %) 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).

(43) http://www.consilium.europa.eu/en/council-eu/preparatory-bodies/working-party-atomic-questions/.
(44) https://ec.europa.eu/health/preparedness_response/risk_management/hsc_en.
(45) http://data.consilium.europa.eu/doc/document/ST-8403-2016-INIT/en/pdf.

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 2017, 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 to be requested by Euratom Member States and HEU quantities to be shipped to the United States 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.

Another issue that will need to be addressed is the medium-term availability of LEU 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. 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 19.75 % LEU ([46]), drafted in 2013 by a Working Group of ESA's Advisory Committee, the Agency organised in November 2017 a dedicated meeting to follow up on the report. The participants agreed that the report, or at least parts of it, needed revisiting and that a proposal should be made to the Advisory Committee at their next meeting in 2018 to reinstate the Working Group of Securing the European Supply of 19.75 % Enriched Uranium Fuel to proceed with this work. The updated report will remain relevant to the international discussion on metallic LEU supply and can provide a useful input to any cooperative initiative in this area, including with interested countries outside the EU.

HEU-LEU 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 ([47]), 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 ([48]) 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 ([49]), 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.

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

(47) http://ec.europa.eu/euratom/docs/2012_council_radioisotopes.pdf.
(48) http://heracles-consortium.eu/.
(49) https://cordis.europa.eu/project/rcn/210823_en.html.

6. ESA's Work Programme for 2018

In line with the remit of the Agency, as per Chapter 6 of the Euratom Treaty and its Statutes, the work programme of ESA for 2018 is built around five specific objectives.

1. **Exercising ESA's exclusive rights and powers in order to maintain a regular and equitable supply of ores and nuclear fuels in the European Atomic Energy Community**

Diversifying sources of supply to prevent excessive dependence on any single external supplier is of paramount importance for the medium- and long-term security of nuclear fuel supply to EU utilities. By evaluating supply contracts submitted to it for conclusion and acknowledging duly notified transactions covering provision of services in the entire nuclear fuel cycle, ESA will continue to work for the security of supply, taking due account of the Commission Communication of 28 May 2014 on the European Energy Security Strategy ([50]). The Agency will continue to focus on supplies of HEU and, increasingly, on future supplies of LEU required for producing medical radioisotopes and fuelling research reactors.

2. **Observing developments in the nuclear market**

ESA will continue to: (i) monitor the nuclear market with a view to identifying trends likely to affect the EU's security of supply; and (ii) produce analyses and reports. In this regard, ESA will continue to support the activities of the Advisory Committee's working groups.

3. **Cooperating with international organisations and third countries**

ESA will actively pursue its relations with international bodies with a view to efficiently carrying out the Nuclear Market Observatory's tasks and contributing to security of supply. Following up the Memorandum of Understanding signed in December 2014 with the US DoE/NNSA, the Agency will, as in previous years, coordinate its implementation in cooperation with the Member States concerned.

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

ESA will continue to follow nuclear technology developments in order to anticipate changes likely to affect the state of the nuclear fuel market.

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

ESA will keep its procedures under review with the aim of further improving the management of the contracts it receives and the operations of its Nuclear Market Observatory. In line with commitments taken in the years before, in 2016 the Agency revised its rules determining the manner in which demand is to be balanced against the supply of ores, source materials and special fissile materials. A Commission decision (as per Art. 60(6) of the Euratom Treaty) approving the new rules received a unanimous favourable opinion of the Agency's Advisory Committee but is still pending.

1. Exercising ESA's exclusive rights and powers in order to maintain 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 apply the principle of equal access to supplies of nuclear materials for all users in the EU Member States. The Agency pays particular attention to the diversification of sources of supply, which has been, and remains, a key priority of the EU energy policy.

ESA monitors the diversification of sources by evaluating contracts submitted to it for conclusion pertaining to the supply of ores, source materials and special fissile materials coming from inside or outside the EU (Article 52 of the Euratom Treaty). The Agency is also kept updated both on the needs and the industrial capacity of undertakings in the EU thanks to notifications it receives of: (i) contracts on the processing, conversion or shaping of materials (Article 75 of the Treaty), and (ii) transactions involving the transfer, import or export of small quantities of materials (Article 74).

(50) COM(2014) 330, final.

ESA will continue to encourage the emergence and use of alternative sources of nuclear fuel/services supply where such sources are currently not available, particularly as regards fuel for VVER power reactors.

ESA will continue to assess potential risks to the security of supply of the HEU and LEU (19.75 %), which are required to produce medical radioisotopes (Mo-99/Tc-99 m) and to fuel research reactors. Neither HEU nor such LEU is currently produced in the EU. As we are in a transition period from HEU to LEU targets and in some cases from HEU fuel to LEU fuel, it is very important to obtain the necessary supplies to prevent any shortage in the production of medical radioisotopes. ESA will be further actively involved in monitoring requirements for these fissile materials and strive to ensure their supply.

Regarding LEU, ESA will continue to take due account of the recommendations of the 'Securing the European Supply of 19.75 % enriched Uranium Fuel' report. The report was produced by a dedicated Working Group of the Agency's Advisory Committee, approved by the latter at its meeting of 14 November 2013 and published in 2016. A proposal should be made to the Advisory Committee at their next meeting in 2018 that the Working Group of Securing the European Supply of 19.75 % Enriched Uranium Fuel be reinstated.

Specific objective No 1

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

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

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 not currently available; liaise in this respect with the operators concerned.

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

6. Support, when requested, the European Commission's nuclear materials accountancy service in its verification of contract data contained in prior notifications of movements of nuclear materials.

7. Verify, when requested, 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. Contribute, when requested, to the preparation of European Commission proposals on broader nuclear energy or general EU energy issues.

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

Acting as the secretariat of the 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. Likewise, as in the previous years, the Agency will provide support to all the working groups set up by the Advisory Committee, as necessary.

ESA will continue to fine-tune its market-monitoring capacity to better respond to operators' expectations.

The aforementioned activities 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 ways to present the Nuclear Market Observatory's analyses. ESA's website will be regularly updated by the Nuclear Observatory, offering direct access to information about 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, ESA will continue to: (i) chair the European Observatory on the supply of medical radioisotopes; and (ii) coordinate actions undertaken by various services involved to enhance the security of supply of Mo-99/Tc-99 m, the most vital medical radioisotope.

Specific objective No 2

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

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

2. regularly update information published by the Nuclear Market Observatory, in particular through the regular publication of *Quarterly Uranium Market Reports*, the *Nuclear Digest* and ad hoc studies;

3. publish its annual report, including market analyses, by July 2018;

4. continue to publish yearly natural uranium price indices: annual long-term and spot, and quarterly price indices;

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

6. update regularly the medical radioisotope section on ESA's website, offering direct access to recent information on this subject;

7. provide support to the activities of the ESA Advisory Committee's working groups as necessary.

3. Cooperating with international organisations and third countries

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

With a view to ensuring regular HEU supplies for as long as necessary, ESA will pursue its cooperation with the US DoE/NNSA, formally initiated through the 2014 Memorandum of Understanding and complemented by the establishment of a list of materials eligible for exchange. The next review meeting on the implementation of the MoU will be held in early 2018.

Specific objective No 3

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 their implementation as regards trade in nuclear fuel.

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

4. 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.

5. Review the conditions for setting up a European LEU facility to cover needs in a larger number of (EU and non-EU) countries, as suggested in the dedicated report of the Agency's Advisory Committee.

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

ESA will continue to monitor, in EU and international research and development forums, R & D activities which are likely to directly influence the nuclear fuel market by having an impact on diversification or on nuclear fuel cycle management — both for electricity generation and for medical radioisotope production (e.g. reprocessing waste, reducing the volume of waste, improving reactor efficiency).

The outcome of the following ongoing projects may be of interest for the Agency:

- HERACLES-CP, a HORIZON 2020 project supported by the European Commission (through the Directorate-General for Research and Innovation (RTD)). The project is 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.

- ESSANUF, i.e. the 'European Supply of Safe Nuclear Fuel', project to qualify nuclear fuel produced by alternative suppliers for VVER-440 power reactors operating in the EU.

Furthermore, as from 2017, the Agency is following the FOR-EvER (Fuel fOR REsEarch Reactors) project intended to secure nuclear fuel supply for European research reactors. The project, which is due to run until 2021, addresses both the conversion of high-performance research reactors (HPRRs) from high- to low-enriched uranium fuels and the monopolistic supply of fuel for medium-power research reactors (MPRRs) with original Soviet design.

Specific objective No 4

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

2. Review the latest technological developments on diversification or fuel cycle management in Advisory Committee meetings or at specifically organised events, where appropriate.

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

The objective is to make ESA more effective and efficient. This is particularly important in the light of the Agency's limited resources.

Specific objective No 5

3. Implement the Agency's new rules determining the manner in which demand is to be balanced against the supply of ores, source materials and special fissile materials. (A Commission decision approving the rules is still pending).

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

5. Continue to ensure sound financial and budgetary management.

Temelin NPP ©CEZ

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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 above address.

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) 2018-2027

Year	Natural uranium		Separative work	
	Gross requirements	Net requirements	Gross requirements	Net requirements
2018	15 803	13 266	12 927	11 004
2019	18 353	15 881	14 960	13 054
2020	16 963	14 893	13 878	12 368
2021	16 003	14 314	13 151	11 917
2022	16 206	14 618	13 382	12 217
2023	16 510	14 250	13 230	11 734
2024	15 157	13 527	11 933	11 136
2025	15 569	13 785	12 710	11 780
2026	15 120	13 430	12 272	11 434
2027	15 349	13 402	12 576	11 655
Total	**161 033**	**141 367**	**131 020**	**118 300**
Average	**16 103**	**14 137**	**13 102**	**11 830**

(B) Extended forecast 2028-2037

Year	Natural uranium		Separative work	
	Gross requirements	Net requirements	Gross requirements	Net requirements
2028	14 727	12 606	12 329	11 557
2029	14 677	12 467	12 215	11 376
2030	14 505	12 388	12 079	11 309
2031	14 265	12 148	11 891	11 121
2032	14 600	12 406	12 155	11 321
2033	14 272	12 090	11 866	11 041
2034	13 925	11 808	11 716	10 946
2035	13 933	11 816	11 686	10 916
2036	13 569	11 452	11 343	10 573
2037	13 551	11 434	11 362	10 592
Total	**142 025**	**120 616**	**118 643**	**110 754**
Average	**14 202**	**12 062**	**11 864**	**11 075**

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**

(*) 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**

(*) 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, 2008-2017 (tU)

Country	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Canada	4 757	3 286	2 012	3 318	3 212	3 156	1 855	2 845	2 946	4 099
Russia	3 272	3 599	4 979	4 524	5 102	3 084	2 649	4 097	2 765	2 192
Niger	1 845	1 854	2 082	1 726	2 376	2 235	2 171	2 077	3 152	2 151
Australia	2 992	3 801	2 153	1 777	2 280	2 011	1 994	1 910	1 896	2 091
Kazakhstan	1 072	1 596	2 816	2 659	2 254	3 612	3 941	2 949	2 261	2 064
Namibia	696	435	1 017	1 011	1 350	716	325	385	504	923
Uzbekistan	1 070	589	459	929	159	653	365	526	115	348
United States	398	318	320	180	241	381	586	343	125	193
Re-enriched tails	688	193	0	0	0	0	0	212	212	171
Other	520	329	432	128	256	621	299	229	130	80
EU	515	480	556	455	421	421	397	412	220	0
HEU feed	550	675	550	731	395	0	0	0	0	0
Malawi	0	0	0	0	180	115	125	2	0	0
South Africa	247	426	190	113	412	17	20	1	0	0
Ukraine		10	0	284	0	0	23	0	0	0
Total	**18 622**	**17 591**	**17 566**	**17 832**	**18 639**	**17 023**	**14 751**	**15 990**	**14 325**	**14 312**

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**
Grand total	**214 727**	**23 806**	**16 096**

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 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

AREVA NC and AREVA NP
AREVA Mines
BHP Billiton
Cameco Inc. USA
Cominak
Energy USA Incorporated
Itochu International Inc
KazAtomProm
Macquarie Bank Limited, London Branch
Nufcor International Ltd
NUKEM GmbH
Rio Tinto Marketing Pte Ltd
Tenex (JSC Techsnabexport)
Traxys North America LLC
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 long-term 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 2015 and 31 December 2017) 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.

In order 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.

As from 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 long-term/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 long-term 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 long-term 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, Marian O'Leary

Director-General of Euratom Supply Agency since 1st November 2016

In my capacity as authorising officer

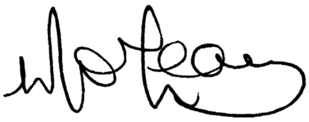
Declare that the information contained in this report gives a true and fair view (51).

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

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

Luxembourg, 27th March 2018



Marian O'Leary

(51) 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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