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# EURATOM Supply Agency

## ANNUAL REPORT 2014

Energy

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# Abbreviations

| | |
|---|---|
| **CIS** | Commonwealth of Independent States |
| **ESA** | Euratom Supply Agency |
| **Euratom** | European Atomic Energy Community (EAEC) |
| **IAEA** | International Atomic Energy Agency (United Nations(UN)) |
| **IEA** | International Energy Agency (Organisation for Economic Cooperation and Development (OECD)) |
| **ITRE** | European Parliament Committee on Industry, Research and Energy |
| **NEA** | Nuclear Energy Agency (OECD) |
| | |
| **(US) DoE** | United States Department of Energy |
| **(US) NRC** | United States Nuclear Regulatory Commission |
| **USEC** | United States Enrichment Corporation |
| | |
| **ERU** | enriched reprocessed uranium |
| **EUP** | enriched uranium product |
| **HEU** | high-enriched uranium |
| **lb** | pound = 0.3732 kg |
| **kgU** | (metric) kilogram of uranium (1 000 g) |
| **LEU** | low-enriched uranium |
| **MOX** | mixed-oxide [fuel] (uranium mixed with plutonium oxide) |
| **RET** | re-enriched tails |
| **RepU** | reprocessed uranium |
| **SWU** | separative work unit (see glossary for detailed definition) |
| **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/WWER** | 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) |

# Foreword

Dear reader,

Let me guide you briefly through the Annual Report of the Euratom Supply Agency (ESA) for 2014.

The report is structured differently from past versions, and focuses on specific matters of importance as reflected in the Agency's activities during the year under review. There are thus two new chapters.

Chapter 4 deals with security of supply, a subject covered in a Commission communication addressed to the European Parliament and the Council in 2014.

Chapter 5 looks at the Agency's activities in the area of radioisotopes, which became central to our work as a result of ESA taking over the chair of the European Observatory on the supply of medical radioisotopes.

The diversification of supply of nuclear materials and services, with a view to preventing excessive dependence on any single external supplier, was a challenging area of work for the Agency in the year under consideration. Diversification is the key to long-term security of supply, according to the European Union (EU) Energy Security Strategy, and ESA, by virtue of its statutory mission and prerogatives, is in a position to ensure efficient implementation of this approach.

At the same time, ESA continued striving to establish the conditions for supply of high-enriched uranium (HEU) for users that still need it, in compliance with international nuclear security commitments. The memorandum of understanding (MoU) signed with the US Department of Energy/National Nuclear Security Agency (DoE/NNSA) was the outcome of these efforts; its implementation will prove challenging, yet it also offers an opportunity to demonstrate international cooperation at its best.

Finally, I wish to commend the work done by the Advisory Committee's working group on prices and security of supply, whose study on the 'Analysis of nuclear fuel availability at EU level from a security of supply perspective' was finalised at the end of 2014. The relevant report will be published after endorsement by the Advisory Committee.

The Agency's team remained stable in 2014. I trust that such continuity, after a few years of unavoidable turnover of staff, will further guarantee the high quality of the Agency's work in the years to come.

Stamatios Tsalas

Director-General of the Euratom Supply Agency

# 1. Nuclear energy developments in the EU and ESA activities

## EU nuclear energy policy in 2014

With the objective of implementing and further developing the framework for nuclear safety, security, non-proliferation and radiation protection, a number of measures were taken at EU level.

### *Nuclear safety directive*

The EU framework for nuclear safety was further reinforced with the adoption of the amended nuclear safety directive on 8 July 2014. Council Directive 2014/87/Euratom ([1]) introduces an EU-wide nuclear safety objective, addressing specific technical issues across the entire life cycle of nuclear installations (siting, design, construction, commissioning, operation and decommissioning of nuclear plants), including on-site emergency preparedness and response. It also reinforces monitoring and exchange of experiences, by establishing a European system of topical peer reviews of nuclear installations. This amended directive, together with the nuclear waste directive and the revised basic safety standards directive adopted by the Council at the end of 2013, provides a consistent EU-wide safety framework covering nuclear installations and nuclear waste management as well as protection of workers and the general population.

### *European Commission — IAEA memorandum of understanding on nuclear safety*

The International Atomic Energy Agency (IAEA) and the European Atomic Energy Community (Euratom) have developed extensive cooperation over many years. On 17 September 2013, the Commission signed an MoU on nuclear safety ([2]) with the IAEA, creating an enhanced framework for cooperation and improved visibility of the actions financed by the EU or implemented with substantial technical assistance. For the purpose of implementing the MoU, a Committee of Senior Officials was established and it had its first meeting on 20 February 2014. To underline this enhanced cooperation, the Commission featured prominently at the annual IAEA General Conference by participating in the Scientific Forum and by organising a joint event with the IAEA on the safety of radioactive waste management and decommissioning of nuclear installations. IAEA Director General Amano's visit to Brussels in February 2014 can be seen as confirmation of the shared interest in enhanced relations between the Commission and the IAEA.

### *Convention on Nuclear Safety*

With regard to the revision of the Convention on Nuclear Safety (CNS) ([3]), Switzerland decided to formally submit an amendment to Article 18 in order to make the principle of 'avoiding off-site contamination' legally binding under the convention in case of a major nuclear accident. The contracting parties, with the support of all Euratom Member States, decided by a two-thirds majority to submit the proposal to a diplomatic conference, which in their view ought to really strengthen the nuclear safety regime worldwide. The diplomatic conference was held on 9 February 2015 at the IAEA headquarters in Vienna, Austria, but the contracting parties concluded that it would not be possible to reach consensus on the proposed amendment. Instead, in order to achieve the same objective as the proposed amendment, the contracting parties unanimously recommended for adoption the 'Vienna Declaration on Nuclear Safety' ([4]), including principles for the implementation of the convention to prevent accidents and mitigate radiological consequences. Accordingly, the contracting parties at the diplomatic conference adopted the Vienna declaration by consensus and committed themselves to its immediate implementation, which will be subject to peer reviews starting in 2017 in the framework of the next CNS review meeting.

([1]) OJ L 219, 25.7.2014, pp. 42-52.
([2]) http://ec.europa.eu/energy/sites/ener/files/documents/20130917_ec_iaea_mou_nuclear_0.pdf
([3]) www-ns.iaea.org/conventions/nuclear-safety.asp
([4]) www.iaea.org/sites/default/files/cns_summary090215.pdf

## Nuclear third party liability and insurance

A stakeholder conference on nuclear third party liability and insurance was organised on 20 and 21 January 2014. It provided an opportunity to present the recommendations to the Commission adopted in 2013 by the expert group on this issue, as well as the outcome of the public consultation carried out by the Commission, also in 2013. Whilst these consultations allowed some areas to be identified, such as cross-border claims management, in which EU action might have an added value, they also demonstrated that further preparatory work is needed, in particular to build a broad consensus amongst stakeholders on the way in which and the extent to which liability amounts of the nuclear operators can be increased, against the background of already existing international conventions.

## Stress tests

Following the Fukushima accident, the March 2011 European Council called not only for comprehensive and transparent risk and safety assessments ('stress tests') of all EU nuclear power plants (NPPs) but also for performance of similar stress tests in the EU's neighbouring countries and worldwide. In this connection, Armenia delivered their stress test report in 2014, which will be peer reviewed in 2015. EU Member States delivered the second national action plan reports for the implementation of their national stress tests on 31 December 2014.

## Off-site nuclear emergency preparedness and response

During the stress tests in 2011 and 2012, it was acknowledged that nuclear off-site emergency preparedness and response measures providing public protection in case of a nuclear emergency are an important area to be reviewed by the European Nuclear Safety Regulators Group (Ensreg) and the Commission. As a first step, the Commission engaged a contractor to review the state of current emergency preparedness arrangements in the EU and neighbouring countries and to propose recommendations for potential improvements, particularly at the European level. Furthermore, the latest Euratom basic safety standards directive — Council Directive 2013/59/Euratom laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom ([5]) — has tightened up the emergency preparedness and response requirements in case of radiological emergencies.

## Radiation protection

The new Euratom basic safety standards directive, which entered into force on 6 February 2014, modernises European radiation protection legislation by taking account of the latest scientific knowledge and technological advancement, as well as of operational experience with current legislation, and consolidates the existing set of five directives into one single piece of legislation. This directive offers better protection for workers, members of the public and patients, and tightens up the requirements for emergency preparedness and response, taking account of lessons learned from the Fukushima accident. Member States are required to bring into force the laws, regulations and administrative provisions necessary to comply with the directive by 6 February 2018. In 2014, a project was launched for the 'Evaluation of Member States' strategies and plans for the transposition of the basic safety standards directive (Council Directive 2013/59/Euratom)'. The objective of this project is to evaluate, at an early stage, the Member States' strategies and plans for the transposition and implementation of the directive and thus facilitate the detection of issues, exchange of experiences and identification of good practices.

Council Directive 2013/51/Euratom laying down requirements for the protection of the health of the general public with regard to radioactive substances in water intended for human consumption ([6]) has to be transposed in the Member States by 28 November 2015. The Commission has already taken action to monitor and support the transposition of the directive into national legislation. It is intended that the requirements laid down in the directive should become a standard element of verifications carried out in Member States under Article 35 of the Euratom Treaty.

On 10 January 2014, the Commission adopted its final proposal ([7]) for a Council regulation laying down maximum permitted levels of radioactive contamination of food and feed following a nuclear accident or any other case of radiological emergency (revision of Council Regulation (Euratom) No 3954/87), after having received the opinion of the European Economic and Social Committee. In December 2014, an agreement was reached at technical level in the Council, pending the opinion of the European Parliament. The regulation is expected to be adopted by the Council by the third quarter of 2015.

## Safe management of radioactive waste and spent fuel

Following adoption in 2011 of the Council Directive establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste ([8]), efforts were focused on assessing implementation by Member States. By the end of 2014, 25 Member States had reported full transposition, one had partially transposed the Directive and two had not yet adopted final transposition measures. A prima facie check of the Member States against which an infringement procedure for non-communication has been launched is underway. Eight cases were closed in 2014. A review of the completeness and conformity of the notified transposition measures is being carried out. A workshop on the implementation of Council Directive 2011/70/Euratom (national programmes) was held in Luxembourg in November 2014.

## EU support for nuclear decommissioning assistance programmes

As provided for in Article 7 of Council Regulations (Euratom) Nos 1368/2013 ([9]) and 1369/2013 ([10]), the Commission adopted

([5]) OJ L 14, 17.1.2014, pp. 1-73.

([6]) OJ L 296, 7.11.2013, pp. 12-21.

([7]) COM(2013) 943 final, 10.1.2014.

([8]) OJ L 199, 2.8.2011, pp. 48-56.

([9]) OJ L 346, 20.12.2013, pp. 1-6.

([10]) OJ L 346, 20.12.2013, pp. 7-11.

detailed implementation procedures for the Bohunice, Kozloduy and Ignalina decommissioning programmes for the period 2014-20. Consequently the Commission adopted the 2014 financing decision together with the Bohunice, Kozloduy and Ignalina annual work programmes, allocating EUR 130.377 million to the nuclear decommissioning assistance programme. These work programmes set out the activities for the calendar year 2014, based on the baseline information for each programme set out in the implementation procedures.

## *Notifications received under the Euratom Treaty provisions*

Seven Commission opinions were delivered in 2014 on general data submitted by Member States concerning plans for the disposal of radioactive waste (Article 37): one on the dismantling of the two gas-cooled reactors of the St Laurent A nuclear power station (France); one on the decommissioning of the Sellafield SMP MOx fuel fabrication plant (United Kingdom) and five on new operations. The latter concern (i) the National Radioactive Waste Repository at Mochovce (Slovakia), (ii) a long-term storage facility at Mochovce (Slovakia), (iii) the 'Diadem' interim storage facility at Marcoule (France), (iv) the 'Atlas' analytical laboratory at Tricastin (France), and (v) the 'sludge packaging plant buffer store' waste treatment plant at Sellafield (United Kingdom).

The Commission adopted six opinions dealing with replacements of important components at NPPs in Finland, Sweden and France under the procedure to notify investments in the nuclear domain (Article 41). Two additional Commission opinions were delivered on the final shutdown and decommissioning of a fast reactor in France and the construction of a high-level radioactive waste facility. Hungary notified the Commission of planned investments in the construction of two Russian-type nuclear power reactors at Paks while discussions continued with a Finnish investor about the planned construction of a Russian-type nuclear reactor at Hanhikivi. Spain communicated two projects dealing with mining and uranium facilities as well as new facilities for high-level radioactive waste. Finally, Finland submitted a first-of-a-kind project dealing with an encapsulation plant along with an underground repository site for spent nuclear fuel. Review, assessment and discussions took place in 2014 for all these projects, and the Commission's points of view are due to be delivered in early 2015.

Several draft agreements involving EU Member States and a third country were assessed by the Directorate-General for Energy (Article 103) to ensure their compliance with the Euratom Treaty and its secondary legislation. Following the adoption of the European Energy Security Strategy ([11]), particular attention is being paid to aspects related to the diversification of fuel supplies when assessing these draft agreements.

## *International agreements on the peaceful use of nuclear energy*

There are currently seven agreements on the peaceful uses of nuclear energy between Euratom and third states (Australia, Canada, Japan, Kazakhstan, Uzbekistan, Ukraine and the United States).

These agreements set out the framework for cooperation in relation to peaceful uses of nuclear energy between the third states and the EU, including provisions governing transfers of nuclear material, non-nuclear material, equipment and/or technology.

The Euratom–South Africa nuclear cooperation agreement was signed in July 2013. However, by the end of 2014, the agreement was still awaiting ratification by South Africa and so has not yet entered into force.

The agreement with Canada which has been in force since 1959 is currently being renegotiated in order to update it and consolidate the various amendments agreed during its lifetime.

In 2014, the Commission formally adopted a proposal for a mandate for the negotiation of a nuclear cooperation agreement with South Korea. This proposal is currently under discussion in the Council working party responsible for this field.

## *European Nuclear Safety Regulators Group (Ensreg)*

Ensreg ([12]) is composed of senior officials from all 28 EU Member States' national regulatory authorities responsible for nuclear safety, radioactive waste safety or radiation protection, plus representatives of the Commission. It is an expert group of the Commission with the objective of assisting in furthering a common approach in Europe to the safety of nuclear installations and the safe management of spent fuel and radioactive waste. During 2014 Ensreg met three times, in January, May and October. Their work in the first half of the year was focused on supporting the finalisation of the revised nuclear safety directive and the implementation of the peer reviews of the nuclear waste directive. In October Ensreg finalised the terms of reference for the second Ensreg national action plan peer review workshop to be held in April 2015. Ensreg also endorsed a draft text for the revision of its MoU with the IAEA to facilitate cooperation in respect of the peer reviews required under the nuclear waste directive.

## *European Nuclear Energy Forum (ENEF)*

The European Nuclear Energy Forum (ENEF) was established in November 2007 as a platform for broad discussion among stakeholders on the opportunities, risks and transparency of nuclear energy. Between its annual plenary sessions, ENEF operates through three working groups focusing on opportunities, risks and transparency.

The 2014 ENEF plenary meeting was held in Bratislava in June. It focused on the importance of affordable and reliable energy and the need to look at the whole energy system approach. At this meeting it was announced that a possible new role for ENEF in the context of the EU energy policy would be discussed by a steering committee; by the end of 2014, it had identified a new approach.

([11]) COM(2014) 330 final, 28.5.2014.

([12]) www.ensreg.eu

### *Euratom safeguards*

The Euratom Treaty requires the Commission to satisfy itself that nuclear materials are not diverted from their intended use. The Euratom safeguards system established for this purpose in 1960 comprises a set of controls and verification activities covering all civil nuclear installations in the EU.

Throughout 2014, the Commission continued to assure citizens that nuclear material is correctly managed and that safeguards obligations with all external parties are complied with. No case of nuclear material diversion was found in 2014 and no irregularities were reported for the EU by the IAEA.

The subsidiary arrangements to the safeguards agreement of 1978 with the IAEA (78/164/Euratom in OJ L 51/1, also known as Infcirc 193) were revised and came into force on 1 March 2014. The updated text now takes into account the accession of new Member States and the entry into force of the Additional Protocol (AP) to Infcirc 193. The subsidiary arrangements cover the implementation of Infcirc 193 and its AP such as reporting formats, correct channels of communication between the organisations, coordination arrangements for joint inspections, and the planning and announcement of inspections and complementary access visits.

### *Nuclear Security Summit*

The EU was invited to and was present at the Nuclear Security Summit (NSS) [13] held on 24 and 25 March 2014 in The Hague. The Commission contribution was coordinated by the Directorate-General for Energy. The 2014 NSS charted the accomplishments of the past four years, identifying which of the objectives set out in the Washington Work Plan (2010) and the Seoul Communiqué (2012) had not been met and proposing ways to achieve them.

## Main developments in the EU Member States

In 2014, against a background of widely differing national energy policies within the EU, emphasis was placed on the creation of an EU energy union, which would be officially launched in early 2015.

Triggered either by changes at government level or by the acknowledgement that nuclear energy represents an economically efficient investment, several EU Member States have put forward new energy policies or programmes which place nuclear energy and its future development at the heart of their power generation mix (e.g. Bulgaria, Poland, Slovakia). Although nuclear plant construction is currently underway in only three countries — Finland, France and Slovakia — governmental approval has been granted for operational lifetime extension of certain NPPs (Bulgaria, the Czech Republic, Hungary) and requests for further lifetime extension of existing units are being introduced. In the period to 2030, nuclear capacity that will be lost due to the closure of a number of reactors — either because they have reached the end of their operating lifetimes or due to political decisions — is expected to outweigh that gained from new reactors. According to latest estimates for the industry, a slight decrease from the current EU nuclear capacity is expected in the short term. Despite long-term delays and significant budget overruns, nuclear projects still attract investors (Slovakia) and progress has been made on new builds in the United Kingdom. Although decisions on some nuclear projects have been postponed (Finland) or cancelled (the Czech Republic — Temelin), further new units likely to come online or be in an advanced stage of construction before 2030 are planned or projected in Bulgaria, Czech Republic, Finland, France, Hungary, Lithuania, Poland, Romania and the United Kingdom.

**Table 1:** Nuclear power reactors in the EU, 2014

| Country | Reactors in operation (under construction) |
|---|---|
| **Belgium** | 7 |
| **Bulgaria** | 2 |
| **Czech Republic** | 6 |
| **Germany** | 9 |
| **Spain** | 7 |
| **France** | 58 (1) |
| **Hungary** | 4 |
| **Netherlands** | 1 |
| **Romania** | 2 |
| **Slovenia/Croatia** [1] | 1 |
| **Slovakia** | 4 (2) |
| **Finland** | 4 (1) |
| **Sweden** | 10 |
| **United Kingdom** | 16 |
| **Total** | **131 (4)** |

(1) Croatia's power company HEP owns a 50 % stake in the Krsko NPP in Slovenia.

*Source:* World Nuclear Association (WNA).

(13) www.nss2014.com

As shown in Table 1, at the end of 2014 a total of 131 nuclear power reactors were in operation in the EU, with four more under construction, the same number as in 2013. The 131 operating NPPs produce 26.9 % of electricity in the EU, with a large spread between different Member States and by different types of reactors.

Russian nuclear reactors in the EU are located in Bulgaria (two), the Czech Republic (six), Finland (two), Hungary (four) and Slovakia (four, with two more under construction). Hungary has an agreement for the construction of two more reactors, and Finland is planning one with Russian equity.

**Country-specific developments in 2014**

**Belgium:** Due to the unplanned outages of three 1 000 MW reactors, Belgium was facing a severe risk of supply shortage and heavy reliance on imported energy. Following the detection of hydrogen flakes in the reactor pressure vessels of Doel 3 and Tihange 2, the two units were temporarily shut down by the operator in March 2014. Results of one mechanical test, carried out as part of a test programme discussed with the Federal Agency for Nuclear Control, were not in conformity with the forecasts of the models used. Both units are currently still offline. Doel 4 was taken off the grid in August after damage caused by an oil leakage in the turbine system, which is still the subject of an inquiry by the Belgian Federal Police. The unit was reconnected to the grid on 19 December 2014.

In November, the energy minister presented to the government a plan including a 10-year life extension for Doel-1 and Doel-2, subject to certain conditions. The newly-formed coalition government pledged to decide by year-end whether to grant the extension for the two 433 MW units, given that it had already put on hold a tender process for 800 MW of new gas-fired capacity intended to fill the gap left by the planned closures of Doel-1 and -2. The process is ongoing.

Managed by the Belgian Nuclear Research Centre (SCK-CEN), the multi-purpose hybrid research reactor for high-tech applications (Myrrha) project moved further towards design completion. After the front-end engineering design was contracted out in 2013 to a consortium led by AREVA, Myrrha entered a new phase in the validation process in 2014, with two new experiments aimed at providing insight into thermo-hydraulics and resistance to earthquakes.

**Bulgaria:** In August, a preliminary shareholders' agreement between Kozloduy NPP-New Build, Kozloduy NPP and Westinghouse Electric Company was signed [14]. The shareholders' agreement is aimed at cooperating in the construction of a new nuclear reactor at the Kozloduy NPP site. Under a resolution of the Council of Ministers (30 July 2014), the agreement will be subject to governmental approval, including the agreement on the financial model and the contract on engineering, procurement and construction. According to the national nuclear legislation, construction work should only start after the decision of the Council of Ministers has come into force.

The latest energy strategy released by the newly elected Bulgarian government indicated that sustaining Bulgaria's nuclear capacity, including the extension of Kozloduy-5's and -6's operational lifetimes, as well as potentially building new nuclear units, remains among the country's key power generation priorities. Currently, Kozluduy-5 (online since 1987) and -6 (online since 1991) are scheduled to run until 2017 and 2019 respectively. Bulgaria intends to extend their operational lifetime up to 60 years from their respective start of operations. In line with this, a new service agreement was signed in October with a consortium (comprising state-owned Russian nuclear companies Rosenergoatom and Rusatom Services, and the French state-owned company, Électricité de France (EDF)), for the life extension of Kozloduy-5.

**Czech Republic:** Launched in 2009, the procurement process for the construction of two new reactors at the Temelin NPP was cancelled by ČEZ in April 2014. The government is hopeful about a possible new tender in the future and is going to prepare a comprehensive plan on the development of nuclear energy in the Czech Republic. According to the Czech prime minister, a likely scenario for building new nuclear plants in the country will be one where the main reactor technology provider is also a financial partner in the project.

CEZ is seeking to obtain a 10-year extension of the operating licence for Unit 1 at the Dukovany NPP, which was due to expire at the end of 2015. In 2016 and 2017, CEZ plans to seek licence extensions for Units 2, 3, and 4 at Dukovany.

**Germany**: In April, the nuclear fuel tax that utilities were paying was suspended by the Hamburg Finance Court, which also decided that the money already paid should be reimbursed. In December, the Federal Finance Court decided with immediate effect that the fuel tax must be paid until a final ruling is taken by the German Federal Constitutional Court and the European Court of Justice on this matter.

The Australian investment bank Macquarie Group purchased Deutsche Bank's uranium portfolio, including their long-term trading contracts and uranium inventory, valued at around United States dollars (USD) 200 million at the end of 2013.

**Spain:** In autumn 2014, the Spanish nuclear plant operator Nuclenor submitted to the country's nuclear regulator a proposal for the restart of the 466 MW Garoña boiling water reactor (BWR), hoping to have it back on the grid within a year and operational until 2031. Spain's seven operational nuclear reactors increased their output by 0.8 % in 2014, raising their capacity factor to 88 % (from 87 % in 2013). In 2014, nuclear energy was the principal source of electricity in the country with a 22 % share of total electricity generation, followed by wind energy with 16.4 % and hydro with 15.5 %.

The state-owned company Enresa, responsible for back-end activities in Spain, submitted the necessary documentation to obtain a licence for the high activity temporary centralised repository.

**France:** On 1 October, the government presented its new 'Energy transition for green growth' bill, which aims to reduce the share of nuclear energy to 50 % of France's power generation, to increase renewable power capacity and to set long-term targets for reducing greenhouse gas emissions. The conditions and deadlines are under discussion in the parliament. As

[14] The shareholders' agreement is available on the Kozloduy NPP website: http://www.kznpp.org

nuclear capacity will be capped, EDF will have to close down some nuclear units before it brings new capacity online. The draft bill does not name any specific reactor. The decision will in principle be made before the authorisation to begin operation is given to the future EPR in Flamanville.

On 18 November, EDF announced that it now expects its 1 650 MW Unit 3 at the Flamanville NPP to start operation in 2017, revising its previous estimate for start-up in 2016. The Réseau de Transmission d'Électricité (RTE) has taken this into account.

Construction is continuing on the Jules Horowitz [research] reactor (JHR) in Cadarache. The JHR is expected to achieve its first criticality in 2019. The current status on the construction site is more than 80 % progress for civil works and increasing contributions of electro-mechanical tasks (recent highlights: polar crane tests and installation of the support structure for the pools liner). The next important milestones will be the installation of main circuit components (for the reactor building), and the completion of the hot cells complex structure (for the nuclear auxiliaries building).

**Italy**: Italian electricity group Enel and China National Nuclear Corp signed an MoU which envisages cooperation on nuclear plant construction, plant operation, fuel supply, environmental remediation of nuclear facilities and nuclear waste management.

**Hungary:** Hungarian nuclear power company MVM Paks II and Russia's Nizhny Novgorod Engineering Company 'Atomenergoproekt', a subsidiary of Russian state-owned nuclear company Rosatom, signed an engineering, procurement and construction contract for the construction of two new 1 200 MW reactors at Hungary's Paks plant. The parliament ratified a EUR 10 billion credit agreement between the governments of Hungary and Russia to finance the construction of two new units at Hungary's Paks NPP. According to the agreement, the loan will cover 80 % of construction costs estimated at EUR 12.5 billion. The fuel supply contract was submitted in December to the Euratom Supply Agency.

Hungary's National Atomic Energy Authority has granted Paks NPP's 500 MW pressurised water reactor (Russian design) (VVER)-440 Unit 2 a permit to operate for another 20 years after its original licence expired at the end of 2014. Unit 1 was granted a 20-year life extension permit in 2012, while similar life extension requests are currently being prepared with regard to Units 3 and 4, whose original licences are due to expire in 2016 and 2017, respectively.

**Netherlands:** The Borssele NPP has been granted ministerial approval to operate until 2034, i.e. an effective operating lifetime of 60 years. Preparatory work for the construction of a new research reactor, the so-called Pallas reactor, as successor to the HFR, is ongoing.

**Poland:** Poland's government released a draft energy policy that calls for measures aimed at reducing the country's dependence on coal, and includes a revised nuclear programme, for which a final investment decision must be taken by 2018. Seen as an economically efficient investment, nuclear power should begin supplying electricity and become a key energy source for the nation after 2025. Two possible scenarios are put forward, for nuclear power either to produce 50 TWh per year by 2035, or to expand more quickly and produce 74 TWh annually by 2050.

**Romania:** In October, Nuclearelectrica announced that China General Nuclear (CGN), the only company that submitted an investment bid before the 9 September 2014 deadline, had been nominated as the selected investor for the partially completed Units 3 and 4 at the Cernavoda NPP. The strategy for the continuation of Units 3 and 4 at Cernavoda NPP, approved by the government through a memorandum, envisages that the private investor will own a majority stake of at least 51 % in the two reactors while Nuclearelectrica will retain a minority share. Presently the civil works are 52 % and 30 % complete and the two units could be operational in 2023 and 2024, respectively.

**Slovakia:** According to Slovakia's nuclear regulator, the completion of two new reactors in Mochovce NPP could be delayed, meaning that the 471 MW Mochovce-3 (80 % complete) could be connected to the grid in the third quarter of 2016, and the similar-capacity Unit 4 in 2017 (presently 60 % ready). Although long-delayed and facing cost overruns, the Mochovce expansion project is receiving a lot of attention following the announcement by Slovenske Elektrarne's (SE) majority owner, ENEL, that it is selling its 66 % stake in SE. Czech utility CEZ submitted in November a non-binding announcement of its interest in buying ENEL's stake, while the Slovak government is also considering this option.

At the same time, the recent long-term energy plan approved by the Slovak government focuses on a cautious development of renewables, reduced dependence on locally produced and imported coal, and a further expansion of nuclear power, through building, by 2030, a new 1 200 MW reactor at the Bohunice site. In case the operation of the two 505-MW units at Bohunice-3 and -4 is not extended beyond 2028, the country will need extra generating capacity. Therefore, Slovenske Ekektrarne has already started the process of having the lifetime of those two units prolonged to 2045, following modernisation.

**Finland:** On 5 December 2014, the parliament gave its approval to an application by Fennovoima for the construction of a 1 200 MW Russian AES-2006 reactor at the Hanhikivi site in northern Finland. Fennovoima and Russian firm Rosatom expect the reactor to begin producing electricity in 2024. Voimaosakeyhtio SF, the consortium of Finnish companies investing in Fennovoima, has increased its share in the Hanhikivi 1 project to 55.5 %, thus approaching the target set by Finland's government that domestic companies should hold an ownership stake of at least 60 % by the time Fennovoima applies for a construction licence in June 2015. Fortum previously announced that it wanted to take a 15 % stake in the project.

In September, the Finnish government rejected Teollisuuden Voima Oyj's (TVO) application to extend the validity period for a decision-in-principle for a fourth reactor (OL4) at the Olkiluoto NPP for an additional five years until 2020, arguing that, due to the uncertainties regarding Olkiluoto 3, it was impossible to evaluate whether TVO could proceed with the project even with an extended schedule.

**Sweden**: Unit 2 at OKG's Oskarshamn NPP, offline since June 2013, is likely to stay idle until the summer of 2015, due to safety upgrades which proved to be more difficult to implement than previously expected. A planned 185 MW power uprate is also likely to be delayed for two years until 2017. The company expects the safety upgrades will enable the Swedish reactor to extend its operating life beyond 2034.

The process for qualifying the Russian fuel fabricator TVEL has started, with the delivery of the first four fuel assemblies to Vattenfall's Ringhals-3 pressurised water reactor (PWR) reactor, loaded into the reactor during the annual outage in June.

Since the need for replacement power occurred later than previously expected and because the new government has initiated an Energy Commission to decide upon the future mix of electricity production, Vattenfall has put on hold its long-term investigation regarding the prerequisites for replacing existing reactors in Sweden. Nevertheless, the company plans to maintain the total lifespan for Units 1 and 2 at the Ringhals NPP at 50 years and the total lifespan for its remaining reactors at 60 years, and plans to proceed with a 100 MW uprate for Unit 1 at Forsmark.

The energy agreement released in October by Sweden's new coalition government states that nuclear power should be replaced by renewables and energy efficiency, without, however, setting a definite timetable. It also calls for stricter safety regulations for NPPs and for nuclear utilities to pay higher fees to the nuclear waste fund used to finance handling of nuclear waste and spent fuel.

**United Kingdom:** In October, the European Commission officially approved the United Kingdom's plans to offer financial incentives for the proposed construction of two EPRs at Hinkley Point C, arguing that the incentives offered by the British government, which include a minimum guaranteed price for electricity and loan guarantees, did not violate EU rules on state aid. The Commission, however, imposed a profit-sharing mechanism that could provide benefits for the government, an approach which could serve as a model for other planned new nuclear construction projects in the EU, for example in eastern Europe. If EDF and its partners make a final decision to build Hinkley Point C, the first of the two EPRs could be operational in 2023. The final ownership composition of the consortium that will build and own EDF Energy's new Hinkley Point C in western England could be known in 2015.

The United Kingdom Office for Nuclear Regulation granted Wylfa-1, the last Magnox reactor still operating in the United Kingdom, permission to continue operations safely until 2024.

The Office for Nuclear Regulation is in talks with GE Hitachi concerning the development of the company's PRISM miniature fast breeder reactor, as a possible option for plutonium disposition in the United Kingdom.

The design approval process for Hitachi and GE's ABWR build has progressed, with regulatory justification from the Secretary for Energy and Climate Change being granted. Horizon Nuclear Power, Hitachi's subsidiary, has already signed an agreement with the United Kingdom Office for Nuclear Regulation, to start purchasing equipment for its planned Wylfa nuclear plant in Wales.

NuGeneration Limited, the 60/40 joint venture between Toshiba and GDF Suez for nuclear plant construction and operation in the United Kingdom, is expected to submit a site licence application to the British government in late 2016 for its planned three Westinghouse AP1000 reactors at the Moorside plant in northern England.

## ESA operations

### *Mandate and core activities*

A common nuclear market in the EU was created by the Euratom Treaty. Article 52 of the Treaty established ESA 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 enhancing the security of supply to users located in the EU and shares responsibility for the viability of the EU nuclear industry. In particular, it recommends that Euratom utilities operating NPPs maintain stocks of nuclear materials, and cover their requirements by entering into long-term contracts with diversification of their sources of supply in order to prevent excessive dependence of EU users on any single, third-country source of supply. Diversification should cover all stages of the fuel cycle from mining to fuel fabrication.

ESA's mandate is, therefore, to exercise its powers and, as required by its statutes, to monitor the market to make sure that the activities of individual users reflect the values set out above.

The Euratom Treaty requires ESA to be a party to supply contracts for nuclear material whenever one of the contracting parties is an EU utility, an operator of a research reactor in the EU or a producer/intermediary selling nuclear material (EU imports or exports, plus intra-EU transfers). When concluding supply contracts, ESA implements the EU supply policy for nuclear materials. ESA also 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. ESA verifies compliance with the upstream contract and acknowledges these notifications.

In 2014, ESA processed 276 transactions, including contracts, amendments and notifications of front-end activities, thus contributing to ensuring the security of supply of nuclear materials.

The ESA 2013 Annual Report was published in July 2014. As every year, ESA presented its annual calculation of different types of average natural uranium prices: MAC-3, multiannual and spot prices.

In 2014, in line with its statutory obligations, ESA's nuclear fuel market Observatory continued to release the *Nuclear news digest*, *Quarterly uranium market reports*, *Price trends* and the weekly *Nuclear news brief* (for readers in the Commission). Greater transparency in the EU natural uranium market reduces uncertainty and strengthens security of supply.

In 2014, ESA issued three *Quarterly uranium market reports* and provided five updates of its *Nuclear news digests*. The

*Quarterly uranium market report* reflects global and specific Euratom developments on the nuclear market. This includes general data about natural uranium supply contracts signed by EU utilities, descriptions of activity on the natural uranium market in the EU and also the quarterly spot-price index for natural uranium whenever three or more ordinary spot contracts have been concluded.

Following a 2013 widening of the Observatory role of ESA to cover aspects of the supply of medical radioisotopes in the EU, ESA continued in 2014 the task of coordinating Commission services' actions undertaken to improve the security of supply of Molybdenum-99/Technetium-99m — the most vital medical radioisotope, chairing the European Observatory on the supply of medical radioisotopes set up in 2012.

In addition to these activities, in October 2014, ESA organised a workshop on contractual procedures and reporting requirements for ESA Annual Reports, attended by EU utilities and by several intermediaries. The workshop was considered a very useful exercise (all presentations are available on ESA's website).

Further to the Commission communication on energy security of 28 May 2014 ([15]) (endorsed by Council conclusions of June and October 2014), which, among other things, stressed the need for nuclear fuel supply diversification, ESA organised a meeting with representatives of the EU utilities which operate VVER-type reactors and those which plan to have this type of reactor (June 2014) and the current and potential alternative fabricators of VVER fuel (October 2014) to explore possible options for fuel fabrication supply diversification and to learn what the Member States intend to do in order to comply with what was agreed upon by the Council in its conclusions on energy security.

## *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 and producers and users in the nuclear industry, as well as Member States' governments.

In 2014, the Advisory Committee met twice. At the first meeting (29 April), the main topics on the agenda were the committee's opinions on ESA's 2013 Annual Report, on ESA's audited accounts for 2013 and on the budget for 2015. The committee also discussed the activities of its working group (WG) on prices and security of supply, which undertook revision of the 'Analysis of the nuclear fuel availability at EU level from a security of supply perspective' report. Updates were given on the work of the European Observatory on the supply of medical radioisotopes and ESA's latest discussions on high-enriched uranium (HEU)/low-enriched uranium (LEU) supply for research reactor fuel and targets used to produce medical radioisotopes. Further discussions focused on the future of the EU common supply policy for nuclear materials (driven by the desire to prevent 'excessive dependence on any external single source of supply') and the latest developments regarding bilateral Euratom agreements with non-EU countries.

The second meeting took place on 13 November, during which ESA's newly appointed Advisory Committee (whose term of office runs from 1 June 2014 to 31 May 2017) elected its chairperson, as well as its first and second vice-chairpersons. The committee discussed progress achieved by its WG on prices and security of supply, with emphasis on the drafting of an analytical report on the nuclear fuel availability at EU level. The committee agreed that the WG should continue its work and appointed its chair and co-chair, as required by the rules of ESA. The committee also provided a positive opinion on the estimate of ESA's revenue and expenditure for the financial year 2016.

Further discussions during the meeting focused on:

— the supply of LEU for research reactors (a draft framework agreement to be concluded between the US Department of Energy and ESA, in order to facilitate the delivery of LEU with < 20 % enrichment);

— the outcome of ESA's 'Workshop on contractual procedures and reporting for the ESA Annual Report';

— ESA's meetings with VVER utilities and the current and potential alternative fabricators of fuel for VVER-type reactors.

A large part of the meeting was devoted to ESA's presentation of its paper on the application of Chapter 6 of the Euratom Treaty to intermediaries acting in the nuclear materials market. The committee stressed the importance of addressing this subject and established a dedicated WG on intermediaries to reflect and discuss further on this matter. Updates were also given on the work of the European Observatory on the supply of medical radioisotopes and negotiations on the bilateral Euratom agreements.

## *International cooperation*

ESA has long-standing and well-established relationships with two major international organisations in the field of nuclear energy: the IAEA and the Nuclear Energy Agency (NEA). In 2014, ESA continued its cooperation with both these organisations by participating in two working groups — the joint NEA/IAEA Uranium Group ([16]) and the NEA High-Level Group on the Security of Supply of Medical Radioisotopes (HLG-MR) ([17]) as well as the Nuclear Development Committee (NDC) ([18]). Additionally, it continued to participate, on an ad hoc basis, in working groups and the nuclear fuel plenary sessions of the WNA. At the WNA plenary session in September 2014, and in the joint NEA/IAEA Uranium Group meeting in October 2014, ESA presented its latest analysis of the EU nuclear market. At the HLG-MR meetings held in January and July 2014, ESA provided an update of the work of the European Observatory on the supply of medical radioisotopes.

([15]) http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52014DC0330

([16]) www.oecd-nea.org/ndd/uranium

([17]) www.oecd-nea.org/med-radio/security

([18]) www.oecd-nea.org/ndd/ndc.html

## ESA administrative issues

### *Financing*

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

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

For its financial operations, the Agency applies the relevant provisions of its statutes as well as the EU financial regulation ([19]) and the accounting rules and methods established by the Commission.

### *Seat*

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

### *Financial accounts and implementation of the budget*

In 2014, the assets owned by the Agency totalled EUR 630 928. They were financed by liabilities of EUR 14 130 (2 %) and equity of EUR 616 798 (98 %). The Agency has a capital of EUR 5 856 000. An instalment of 10 % of the capital is paid at the time of a Member State's accession to the EU. On 31 December 2014, the amount of the instalment called up and reflected in ESA's accounts stood at EUR 585 600.

In 2014, the Agency's budget remained stable, amounting to EUR 104 000. Its revenue and expenditure were in balance. The budget was financed by a contribution from the Commission's heading 32.01.07 'Euratom contribution for operation of the Supply Agency' (EUR 98 000) and by own revenues (bank interest on the paid-up capital, for approximately EUR 6 000).

ESA's expenses consist only of administrative costs. The Agency does not manage operational budget lines nor does it provide grants. The bulk of the Agency's administrative expenses, including salaries, premises, infrastructure, training, and some IT equipment, is covered directly by the budget of the Commission, and is not recognised in the Agency's accounts. Notably, salaries are paid by the Commission in line with the provisions of 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. Thus, ESA's running costs are covered partly by its own budget, basically staff missions and IT equipment for its own computer centre.

The financial statements of ESA as of 31 December 2014 reveal a budget execution in the order of EUR 95 000 or 91 % of commitment appropriations (against 95 % in 2013). 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, on the basis of its audit, to provide the European Parliament and the Council with a statement of assurance as to the reliability of the annual accounts and the legality and regularity of the underlying transactions.

ESA takes due account of the opinions expressed by the court. In 2014, the European Court of Auditors provided an unmodified opinion on the reliability of the accounts and on the legality and regularity of the underlying transactions for the financial year 2013.

### *Staff*

After the high staff turnover in 2013, the Agency's staff did not change in 2014. At the end of the year, there were 17 permanent posts and one contract agent post. The staff of the Euratom Supply Agency are European Commission officials, in accordance with Article 4 of ESA's statutes ([20]).

([19]) 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.

([20]) 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.

# 2. World market for nuclear fuels

This chapter presents a short overview of the main developments in 2014 affecting the global supply and demand balance and security of supply at different stages of the fuel cycle. The information has been gathered from various specialised publications.

According to the WNA, as of 31 December 2014 there were 437 nuclear reactors operational in 30 countries, able to generate 377.8 GWe of electricity and to supply approximately 11 % of the world's requirements. More importantly, in 2014 there were 70 nuclear reactors under construction in 14 countries, with China, Russia, India, South Korea and the United States leading this expansion (totalling together 52 reactors under construction).

According to the Organisation for Economic Cooperation and Development (OECD)/NEA and the IAEA 'Red Book' — *Uranium 2014: Resources, production and demand* — by the year 2035, world nuclear capacity is projected to grow to between about 400 GWe net in the low demand case and 680 GWe net in the high demand case, representing increases of 7 % and 82 % respectively. Accordingly, world annual reactor-related uranium requirements are projected to rise to between 72 000 tU and 122 000 tU by 2035. In addition to downward projections of nuclear generating capacity, uranium requirements have been reduced from 2011 on the assumption that tails assays at enrichment plants have been reduced, on average, from 0.30 % to 0.25 %.

The East Asia region is projected to experience the largest increase by 2035, with between 57 GWe and 125 GWe of new capacity installed in the low and high cases respectively, which would represent increases of more than 65 % and 150 % over 2013 capacity. It is expected that nuclear capacity in the non-EU Member State countries of Europe will also increase considerably, with additions of between 20 GWe and 45 GWe of capacity projected by 2035 (increases of about 50 % and 110 % respectively). Other regions where it is estimated that nuclear capacity will significantly increase include the Middle East, Central and Southern Asia and South-East Asia, with more modest growth projected in Africa and the Central and South American regions. For North America (NA), nuclear generating capacity in 2035 is projected to either decrease by almost 30 % in the low case or increase by over 15 % in the high case. In the European Union the outlook is similar, with nuclear capacity in 2035 projected either to decrease by 45 % in the low case scenario or to increase by 20 % in the high case scenario.

China has a very ambitious new build programme underway; further to the 20 reactors already in operation (producing approximately 17 GWe), there were 27 reactors under construction at the end of 2014 (an additional 30 GWe), anticipated to be in operation by mid-2018. As happened in 2013, reactors in Japan remained shut down, while at the same time some non-nuclear countries continued with their plans for new builds, such as Saudi Arabia, which plans to build up to 16 reactors, and the United Arab Emirates, with three reactors under construction and contracts for one additional reactor.

Low levels of uranium prices throughout 2014 have caused the shutdown of some operations and the delaying of several uranium projects. Prices are likely to increase to support the development of new mines which will be required to meet existing demand and projected increases in future demand.

## *Natural uranium production*

In 2014, global uranium production dropped by 5 % as compared with the 2013 figure, totalling approximately 56 200 tonnes of uranium. As in 2013, the top three uranium-producing countries were Kazakhstan, Canada and Australia.

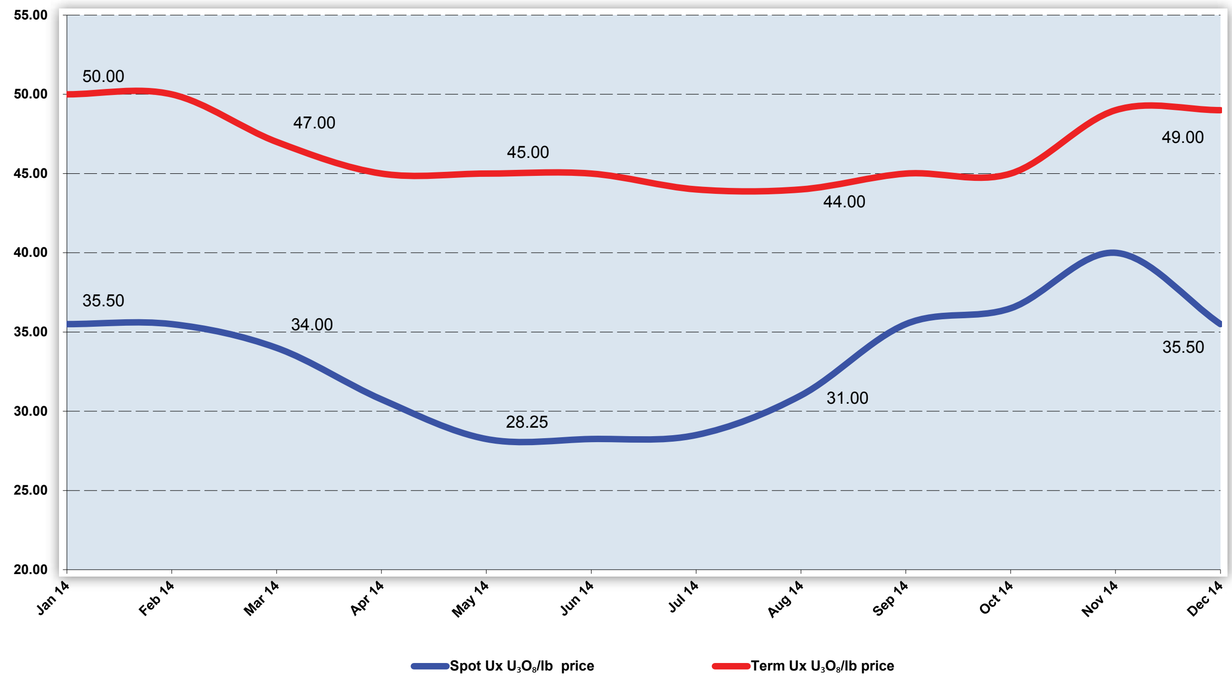
Kazakhstan remained the world's leading uranium producer in 2014, with 41 % of total uranium output worldwide. The country's uranium production accounted for approximately 23 100 tU in 2014, a 3 % increase compared to the 2013 figure. Canada's production is estimated at around 9 100 tU in 2014, a 2 % drop from the 2013 data. Australia's production remained on the decline, totalling around 5 000 tU at the end of 2014, a 21 % drop compared to 2013.

**Table 2:** Natural uranium estimated production, 2014 (compared with 2013, in tonnes of uranium)

| Region/country | Production 2014 (estimate) | Production 2013 (final) | Share in 2014 (%) | Share in 2013 (%) | Change 2014/13 (%) |
|---|---|---|---|---|---|
| Kazakhstan | 23 127 | 22 451 | 41 | 38 | 3 |
| Canada | 9 134 | 9 331 | 16 | 16 | – 2 |
| Australia | 5 001 | 6 350 | 9 | 11 | – 21 |
| Niger | 4 057 | 4 518 | 7 | 8 | –10 |
| Namibia | 3 255 | 4 323 | 6 | 7 | – 25 |
| Russia | 2 990 | 3 135 | 5 | 5 | – 5 |
| Uzbekistan | 2 400 | 2 400 | 4 | 4 | 0 |
| United States | 1 919 | 1 792 | 3 | 3 | 7 |
| China | 1 500 | 1 500 | 3 | 3 | 0 |
| Ukraine | 926 | 922 | 2 | 2 | 0 |
| Others | 963 | 985 | 2 | 2 | – 2 |
| South Africa | 576 | 531 | 1 | 0 | 8 |
| Malawi | 369 | **1 132** | **0** | **2** | **– 67** |
| **Total** | **56 217** | **59 370** | **100** | **100** | **– 5** |

*Source:* Data from WNA and specialised publications (totals may not add up due to rounding).

**Figure 1:** Monthly spot and term $U_3O_8$/lb prices (USD)




*Source:* The Ux Consulting Company.

The spot price indicator reflected increased volatility in 2014. It started the year at around USD 35.50 per pound, which was the price level for the first quarter. In April, the spot price indicator started to decrease, falling in May to its lowest level of the year, USD 28.25 per pound. In the second half of the year the price picked up and reached USD 40.00 per pound in November, ending the year at USD 35.50 per pound.

In 2014, the persistent downward trend in the spot market influenced the decline of the long-term contract prices. The long-term indicator started the year at USD 50.00 per pound but had fallen to USD 45.00per pound by April. After a further slight decrease in July, the term price rebounded to USD 45.00 per pound and finally increased to USD 49.00 per pound in November, which was the end-year price.

## *Secondary sources of supply*

Natural uranium production supplies approximately 89 % of current demand, the balance on the market being ensured by supply derived from secondary sources. In 2014, the uranium supplied from secondary sources included stockpiles of natural and enriched uranium, either held by governments or in the form of commercial inventories, down-blended weapons-grade uranium, reprocessed uranium (RepU) and plutonium extracted from spent fuel, re-enriched uranium tails and uranium saved through underfeeding.

Over recent years, secondary supplies have shown a downward trend. According to sources like UxC, the level of secondary sources of supply is likely to decrease, from 13 463 tonnes of uranium (35.0 million pounds) in 2014 to around 11 231 tonnes (29.2 million pounds) per year by 2020.

While the Megatons to Megawatts programme ended in 2013, the United States Enrichment Corporation (USEC) will continue to purchase, until 2022, LEU from Tenex, arising from Russia's commercial enrichment activities rather than the down-blending of Russian weapons material. Under the new agreement, the amount delivered in 2015 should reach about 50 % of the quantities supplied under the Megatons to Megawatts programme.

Government inventories are still a significant source of secondary supplies, particularly in the United States and Russia, the disposition of which may have a market impact over the next 10 to 20 years. However, it is difficult to assess when and at what pace this material will be entering the market.

## *Uranium exploration and mine development projects*

Over the last five years a number of new mines have been brought into production in Kazakhstan and Africa. As indicated above, primary production currently covers approximately 89 % of demand. But since the demand is expected to increase due to new reactor build, a gradual restart of Japanese reactors and diminishing secondary supplies, more mines will be required.

In 2014, as a result of low uranium prices, several uranium development projects were delayed and some current production sources were shut down.

Early in 2014, AREVA resumed production at its Somair and Cominak uranium mines, for the exploration of which the French company signed in May 2014 a new five-year production contract with Niger. Under the deal, AREVA agreed, among other things, to a reduction in tax breaks and an increase in royalty rates at those mines. The start of production at its new Imouraren mine in Niger is likely to be delayed until uranium prices improve.

The Czech government announced that it is considering reopening the Brzkov uranium deposit, which was in an advanced stage of exploration in the late 1980s, as the operating Rožná mine is nearly exhausted and due to cease operation after mid-2017. The Brzkov deposit contains currently estimated resources of 3 000-4 000 tU (7.7-10.3 million pounds $U_3O_8$) and, according to the state-owned mining firm Diamo, around 6 or 7 years would be needed for the start-up of operations there, with a mine life of around 16 years.

In May, Paladin Energy Ltd announced that uranium production had ceased at the Kayelekera mine in Malawi. The company linked the unfortunate outcome, resulting in a reduction of approximately 3.3 million pounds $U_3O_8$ (~ 1275 tU) per year on the global uranium market, directly to the continuing deterioration in uranium prices.

In May, uranium mining operations got underway at the Husab project in Namibia. Construction of the Husab mine is expected to be completed by the end of 2015, with production planned for up to 5 770 tU (~15.0 million pounds $U_3O_8$) per year by 2017. This open pit mine with measured and indicated reserves of about 140 000 tU (~364 million pounds $U_3O_8$), has an operating lifetime estimated at 20 years, at least. According to CGN, the Husab mine has sufficient reserves to supply enough uranium to power 20 GWe of nuclear capacity for almost 40 years. Once up and running, Husab will become the fourth uranium  mine in operation in Namibia.

In June, the Four Mile uranium mine in South Australia, first discovered in 2005, officially started production. The mine is operated by a joint venture between Quasar Resources and Alliance Resources and ore is being processed at the nearby Beverley uranium mine site. The 2014 output was estimated to reach 1.6 million pounds $U_3O_8$ (~ 618 tU), despite official statements placing the current cost of production at the mine higher than the world uranium price.

In September, Russia and Algeria signed an intergovernmental agreement on cooperation in nuclear energy, including with regard to uranium prospecting and mining, thus paving the way for the possible construction of a nuclear power plant in the North African country.

In October, Indústrias Nucleares do Brasil (INB) officially confirmed that mining operations at the Engenho uranium deposit would begin in 2015. With an estimated output of 4011 tU (10 406 pounds $U_3O_8$) over a 14-year lifetime, the mine would yield a little less than 286 tU (748 pounds $U_3O_8$) per year. Output from the open pit operations will be processed at the nearby Caetité mill. The mill is undergoing a USD 90 million expansion programme that will ultimately increase its capacity to 670 tU (1 735 pounds $U_3O_8$) per year.

The first uranium ore from the Cigar Lake mine was processed in October 2014 at the McClean Lake mill, after its facilities were modified to enable processing of the high-grade uranium ore. Mining at Cigar Lake began in March, following a 9-year development project which saw operator Cameco face the challenges of mining the world's second largest high-grade uranium deposit. The mine secures Cameco's future supply capacity, as the Rabbit Lake mine is expected to be exhausted soon.

## *Conversion*

Primary conversion plants, operating commercially in the United States, Canada, France, Russia and China meet the majority of the global demand for $UF_6$ conversion services. The main new plant is Areva's Comurhex, operating between two sites in France. China's capacity is expected to grow considerably through to 2025 and beyond, to keep pace with domestic requirements.

In 2014, world nameplate conversion capacity was estimated at around 71 000 tU, which was well above the global demand for conversion services, estimated to be around 62 000 tU. Part of the supply, around 20 000 tU, continued to be provided by the secondary conversion sources (almost all secondary uranium sources which displace demand for primary $UF_6$ conversion services).

## Table 3: Commercial $UF_6$ conversion facilities (tonnes of uranium/year)

| Company | Nameplate capacity in 2014 (tU as $UF_6$) | Share of global capacity (%) |
|---|---|---|
| Atomenergoprom (Rosatom) (Russia) | 25 000 (*) | 35 |
| Cameco (Canada) | 12 500 | 18 |
| ConverDyn (United States) | 15 000 | 21 |
| Comurhex (AREVA) (France) | 15 000 | 21 |
| CNNC (China) | 3 650 | 5 |
| Ipen (Brazil) | 40 | 0 |
| **Total nameplate capacity** | 71 190 | 100 |

*Source:* WNA, The global nuclear fuel market — Supply and demand 2013–30.
(*) Operating capacity estimated at 10 000 tU/y.

Following a manual shutdown which occurred in January 2014 due to a potentially unsafe valve configuration at Cameco's Port Hope conversion plant, the Canadian Nuclear Safety Commission requested that the plant remain offline until satisfactory corrective measures had been taken.

In April 2014, TVEL shut down its conversion plant in Angarsk, the larger of Russia's two conversion facilities. Accounting for some 60 % of the country's nominal conversion capacity of approximately 25 million kgU as $UF_6$, the facility had been set to close in 2016, but it closed earlier because the plant was operating at less than full capacity.

Faced with the conditions of a weak conversion market, Cameco Corp. announced its plans to put a stop to its toll-conversion agreement with Westinghouse's subsidiary, Springfields Fuels Ltd, subject to payment of USD 18 million as a penalty for early cancellation. Previously set to expire in 2016, production for Cameco at Springfields ended in August 2014.

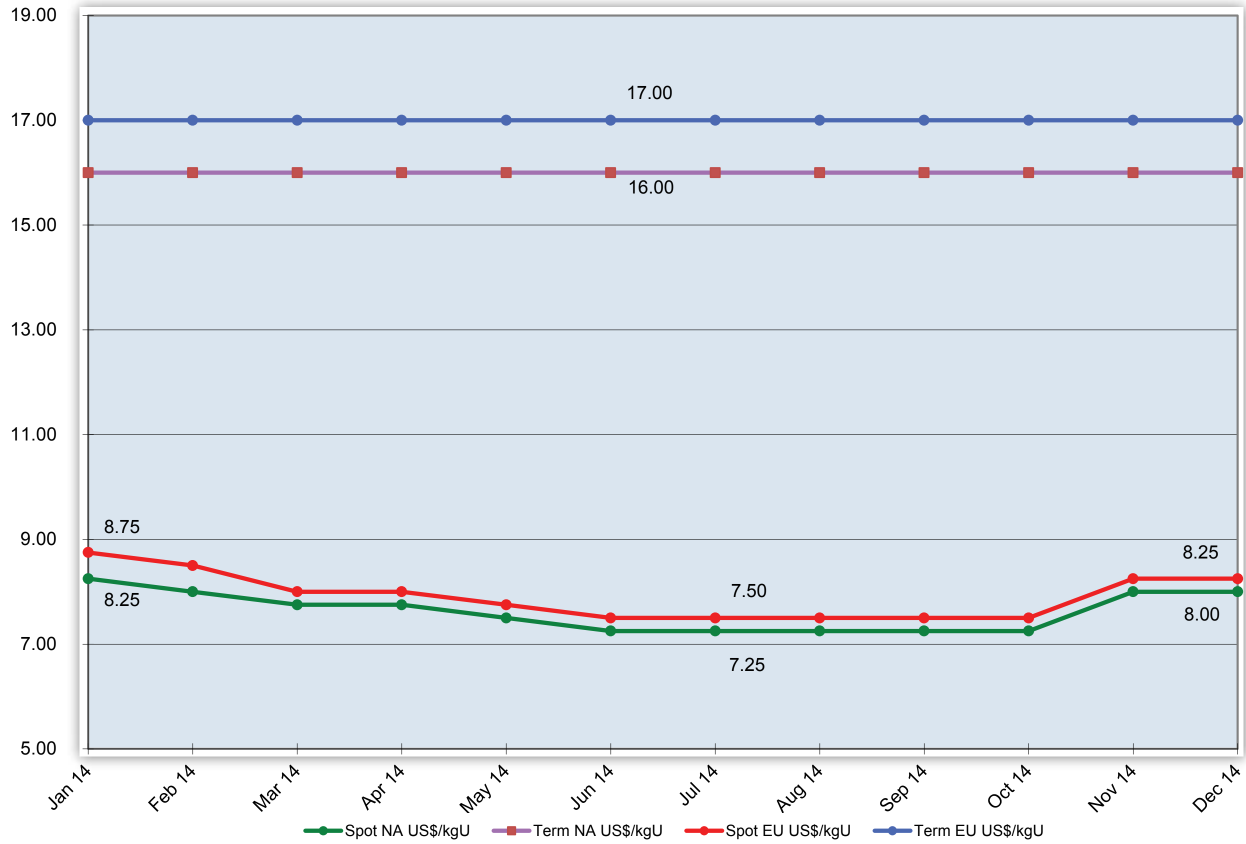
Also in August, Canada and Kazakhstan signed an agreement for cooperation in the peaceful uses of nuclear energy, providing for a common investment of about USD 200 million to develop a 12 000 tonnes $UF_6$ conversion facility at the Ulba Metallurgical plant in Ust-Kamenogorsk.

In November, Honeywell announced that the Metropolis conversion plant had resumed production, after completion of the investigation of a leak that occurred in October, caused by failure of a piece of equipment. The company plans to invest approximately USD 15 million in additional safety enhancements in 2015.

During the first half of 2014, both European and North American spot conversion prices dropped steadily from the end-of-2013 levels of USD 9.00 per kgU and USD 8.50 per kgU, respectively, to USD 7.50 per kgU and USD 7.25 per kgU. In the third quarter, the prices remained flat, and then increased in November to USD 8.25 per kgU in the EU and to USD 8.00 per kgU in the US. These were the price levels until the end of the year.

The European and North American term conversion prices were stable in 2014 and amounted to USD 17.00 per kgU and USD 16.00 per kgU, respectively.

**Figure 2:** Uranium conversion price trends (USD)




*Source:* The Ux Consulting Company.

## *Enrichment*

In 2014, the demand for enrichment services was evaluated at around 50 000 tSW. Large commercial enrichment plants are in operation in France, Germany, the Netherlands, the United Kingdom, the United States and Russia, with smaller plants elsewhere. China's capacity is expanding considerably, in line with domestic requirements. With surplus capacity, most of the enrichment plants operate at low tails assays (underfeeding) to produce low-enriched uranium for sale.

Despite estimates pointing to an increase in enrichment requirements over the 2013-30 period, mainly due to the new nuclear builds planned in Asia and the Middle East, the current commercial enrichment nameplate capacity of over 56 000 tSW is considered to be sufficient to cover demand until 2020.

**Table 4:** Operating commercial uranium enrichment facilities, with approximate 2014 capacity

| Company | Nameplate capacity (tSW) | Share of global capacity (%) |
|---|---|---|
| Atomenergoprom (Russia) | 28 000 | 50 |
| Urenco (United Kingdom/Germany/Netherlands/United States) | 18 100 | 32 |
| AREVA-GBII (France) | 7 500 | 13 |
| CNNC (China) | 2 900 | 5 |
| JNFL (Japan) | 75 | 0 |
| **World total** | 56 575 | 100 |

*Source: UxC special report*, 'Enrichment supplier assessment', and data from industry.

During the first quarter of 2014, USEC filed for voluntary bankruptcy as part of a financial restructuring plan, confirmed in September 2014 by the bankruptcy court for the District of Delaware. The company subsequently emerged under the name of Centrus Energy Corp. The new capital structure allows for greater financial flexibility to support the American centrifuge project (ACP), namely funding of the American centrifuge technology demonstration and operations programme (ACTDO) through to 30 September 2015. The Department of Energy took over management of the ACP from USEC in May 2014.

In April 2014, the Urenco United States uranium enrichment plant completed its second phase, with the plant working at a capacity of 3.7 million separate work units (SWUs). The company aims at bringing the total capacity of the plant to approximately 5.7 million SWUs.

In November 2014, Company Industrias Nucleares do Brasil (INB) reported that its uranium enrichment plant at Resende will provide $UF_6$ for the first time for Unit 1 of the country's Angra NPP. Currently, the plant has the capacity to meet 80 % of the NPP's enriched fuel needs, but there are plans to expand it to 100 %.

## *Fabrication*

Nuclear fuel fabrication is a specialised service rather than a commodity transaction, and the main fuel manufacturers are also the main suppliers of NPPs, or connected to them. The largest fuel manufacturing capacity can be found in the EU (Germany, Spain, France, Sweden and the United Kingdom), Russia and the United States, but fuel is also manufactured in other countries, often under licence from one of the main suppliers.

In the EU, AREVA, Westinghouse and Genusa continued to be awarded contracts from various EU utilities. In October, AREVA announced the signing of a fuel fabrication contract with EDF for the period 2015-21. The agreement includes technical cooperation aimed at improving nuclear fuel performance, and AREVA says it has already identified an opportunity to cooperate with EDF on a new type of fuel known as GAIA. In November, Westinghouse announced that it had signed contracts with RWE and E.ON to supply fabricated fuel for the Gundremmingen and Emsland NPPs in Germany. The contract includes two fuel deliveries from the Västeras facility for each NPP between 2016 and 2018, as well as two optional deliveries for each NPP in later years. AREVA will also deliver fuel assemblies to Emsland in the years 2016-20 from its fabrication plant in Lingen. Genusa was awarded a contract for five deliveries for Gundremmingen of fuel assemblies to be fabricated by ENUSA in Spain.

TVO announced that it had renewed fuel fabrication contracts with both AREVA and Westinghouse, securing supply of nuclear fuel for Units 1 and 2 at its Olkiluoto NPP over the 2016-19 period.

In 2014, fuel fabricators were also active on the non-EU global nuclear fuel market. In April, Ukraine's national electricity utility, Energoatom, amended its nuclear fuel supply contract with Westinghouse, securing deliveries until 2020. Pursuant to the contract originally signed in 2008, Westinghouse has supplied nuclear fuel assemblies to be used at the south Ukraine nuclear power plant (VVER-1000 PWRs). The fuel will be produced at the Västerås fabrication facility in Sweden.

India's Ministry of Environment and Forests plans to grant environmental clearance for the construction of the country's second nuclear fuel fabrication facility, to be located at Rawabhata in the state of Rajasthan. Preliminary work on the project is already underway. The plant is expected to have an annual fuel fabrication capacity of 500 tonnes.

In December, Kazatomprom and China General Nuclear Power Corporation (CGNPC) signed an agreement on mutual cooperation in nuclear power, providing, inter alia, for the development of strategic cooperation in the fields of nuclear fuel production, peaceful uses of nuclear power, and transiting of uranium products through China and Kazakhstan. The agreement also mentions the creation of a joint venture for the production of fuel assemblies in Kazakhstan for the needs of Chinese NPPs, with a manufacturing output expected to reach 200 tonnes of enriched uranium product (EUP) equivalent.

## *Reprocessing and recycling*

The recovery of uranium and plutonium through reprocessing of spent fuel is nowadays done in France, the United Kingdom and Russia. Fabrication of the recovered material for further use in reactors requires dedicated conversion, enrichment and fabrication facilities.

Nuclear cooperation between France and China has been extended through the signature, in March 2014, of a strategic partnership between AREVA and CNNC for 'the identification of all the opportunities in all civil nuclear fields, in the fuel cycle as well as reactors and services', which covers, inter alia, nuclear power plant safety and used fuel recycling.

In April 2014, the fourth and largest shipment so far of high-level waste from the United Kingdom to Japan was completed. Resulting from the reprocessing at Sellafield of Japanese used reactor fuel, this high-level waste should be returned from the United Kingdom to Japan by the end of the decade. Overall, this latest shipment was the 16th of its type from Europe to Japan since 1995 (the repatriation of high-level waste from Japanese fuel reprocessed in France was completed in 2007).

The Japan Atomic Energy Agency (JAEA) is planning to close the Tokai Reprocessing Plant as early as 2015, after concluding that upgrading the facilities according to new regulatory standards would be too expensive. Therefore, most reprocessing technologies have been transferred to the Japan Nuclear Fuel Limited's Rokkasho reprocessing facility. However, in November 2014, JNFL announced that the long-delayed Rokkasho reprocessing plant would not begin operating until early 2016.

In December 2014, AREVA announced that it had completed fabrication of its 4 000th mixed-oxide (MOX) fuel assembly, delivered to a European utility.

For the back-end of the fuel cycle management, Russia follows a four pillar strategy: (1) completion of the MOX fuel fabrication plant for fast reactors fuel this year; (2) operation of a pilot demonstration centre for used nuclear fuel reprocessing expected to start in 2016; (3) replacement, in the medium term, of the current RT-1 reprocessing facility by a full-scale RT-2 facility, able to reprocess VVER, light water graphite-moderated reactor (RBMK) and BN reactor used fuel with the aim to further produce MOX fuel or Remix — the regenerated mixture of uranium and plutonium oxides; (4) replacing of the current spent fuel pool storage by a dry storage facility.

It is expected that the recycling of RepU and plutonium (in MOX fuel) will still play a role in meeting the demand for nuclear fuel, as replacement of fresh LEU. However, future developments in this area will continue to depend upon natural uranium price levels and timely processing by the existing facilities. Currently, around 100 t/y of ERU are produced at MSZ in Elektrostal for AREVA contracts. Based on the information available on secondary supplies, it is estimated that supply of ERU and MOX fuel will displace usage of enrichment capacity up to the level of 3 million SWUs/y until 2020 and 4 million SWUs/y into the next decade, mainly due to Japan's resuming use of MOX fuel ([21]).

([21]) WNA, *The global nuclear fuel market — Supply and demand 2013-30*, p. 203.

# 3. Supply of and demand for nuclear fuels in the EU

This overview of nuclear fuel supply and demand in the EU is based on information provided by the utilities or their procurement organisations in an annual survey of acquisition prices for natural uranium, the amounts of fuel loaded into reactors, estimates of future fuel requirements, quantities and origins of natural uranium and separative work, and future contracted deliveries and inventories. At the end of 2014, there were 131 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 Commission in 2014, gross electricity generation for the total of the countries of the EU (EU-28) amounted to 876.8 TWh in 2013 and nuclear gross electricity generation accounted for 26.9 % of total EU-28 production ([22]).

## Fuel loaded into reactors

In 2014, 2 165 tU of fresh fuel was loaded into commercial reactors in the EU-28. It was produced using 15 355 tU of natural uranium (NatU) and 582 tU of RepU as feed, enriched with 11 434 tSW. The quantity of fresh fuel loaded decreased by 8 % (i.e. 178 tU less than in 2013). In 2014, the fuel loaded into EU reactors had an average enrichment assay of 3.85 %, with 80 % of assays falling within the range of between 3.14 % and 4.57 %. An average tails assay was 0.24 %, falling mostly within the range of 0.22 % to 0.25 %.

In 2014, MOX fuel was used in a number of reactors in Germany, France and the Netherlands. The quantity of MOX fuel loaded into NPPs in the EU totalled 11 603 kg plutonium (Pu) in 2014, a 4 % increase over the 11 120 kg Pu used in 2013. Use of MOX resulted in estimated savings of 1 156 tU and 825 tSW (see Annex 5).

([22]) Eurostat energy statistics, 2013, data on primary energy production.

When the whole amount of fuel loaded into the EU reactors in 2014, including natural uranium feed, RepU and MOX fuel is added up, we get the figure of 17 094 tU requirements for the reference year. The quantity of natural uranium originating in the EU accounts for approximately 400 tU per year, which together with savings in natural uranium resulting from MOX fuel and RepU usage gives the quantity of feed material coming from indigenous and secondary sources. All this provides for about 12.5 % of the EU's annual natural uranium requirements.

**Table 5:** Natural uranium included in fuel loaded by source, 2014

| Source | Quantities (tU) | Share (%) |
|---|---|---|
| Uranium originating from outside the EU | 14 955 | 87.5 |
| Uranium originating from within the EU (approximate annual production) | 400 | 2.3 |
| Reprocessed uranium | 582 | 3.4 |
| Savings from MOX | 1 156 | 6.8 |
| Total annual requirements | 17 094 | 100 |

## Future reactor requirements (2015-34)

EU utilities have estimated their gross reactor requirements for natural uranium and enrichment services over the next 20 years, taking into account possible changes in national policies or regulatory systems resulting in the construction of new units, lifetime extensions, the early retirement of reactors, phasing-out or decommissioning. Net requirements are calculated on the basis of gross reactor requirements after subtracting savings resulting from planned uranium/plutonium recycling and inventory usage.

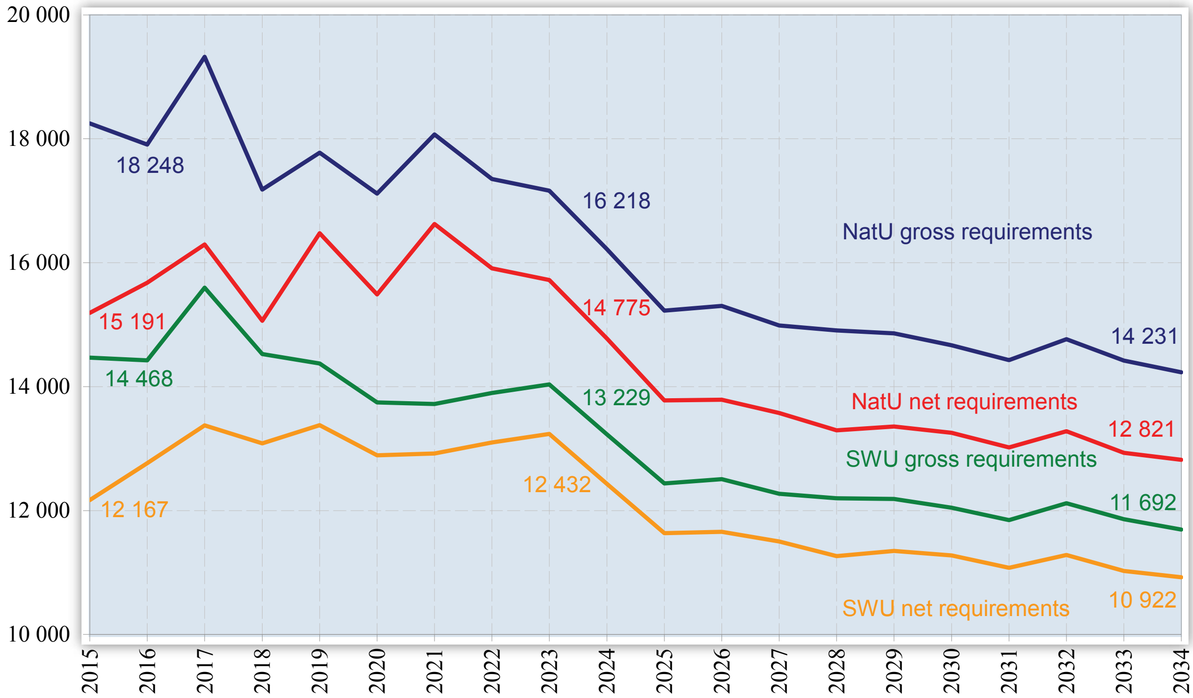
| Natural uranium — average reactor requirements | | |
|---|---|---|
| 2015-24 | 17 635 tU/year (gross) | 15 722 tU/year (net) |
| 2025-34 | 14 779 tU/year (gross) | 13 310 tU/year (net) |

| Enrichment services — average reactor requirements | | |
|---|---|---|
| 2015-24 | 14 201 tSW/year (gross) | 12 935 tSW/year (net) |
| 2025-34 | 12 116 tSW/year (gross) | 11 299 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 3 (see Annex 1 for the corresponding figures).

Compared with last year's annual survey, future aggregate requirements declared by the utilities have decreased for both decades. For the period 2015-24, forecasts of average gross requirements for natural uranium have fallen by 3 % (– 569 tU) and for separative work by 2 % (– 314 tSW). Likewise, for 2025-34, the drop in demand for gross natural uranium is calculated at 10 % (– 1 603 tU) and for enrichment services at 8 % (– 1 120 tSW).

**Figure 3:** Reactor requirements for uranium and separative work (EU-28) (tonnes natural uranium (NatU) or SWU)




## Supply of natural uranium

### *Conclusion of contracts*

In 2014, ESA processed a total of 81 contracts and amendments, of which 59 (73 %) were newly concluded contracts. Out of 48 new purchase/sale contracts, 52 % involved EU utilities and the remainder were signed by intermediaries. Table 6 gives further details of the type of supply, terms and parties involved.

**Table 6:** Natural uranium contracts concluded by or notified to ESA (including feed contained in EUP purchases)

| Type of contract | Number of contracts concluded in 2014 | Number of contracts concluded in 2013 |
|---|---|---|
| **Purchase/sale by an EU utility/user:** | **25** | **18** |
| — multiannual (1) | 9 | 2 |
| — spot (1) | 16 | 16 |
| **Purchase/sale by intermediaries:** | **23** | **29** |
| — between intermediaries (2) (multiannual) | 4 | 6 |
| — between intermediaries (2) (spot) | 19 | 23 |
| **Exchanges and loans (3)** | **11** | **3** |
| **Amendments** | **22** | **26** |
| **Total (4)** | **81** | **76** |

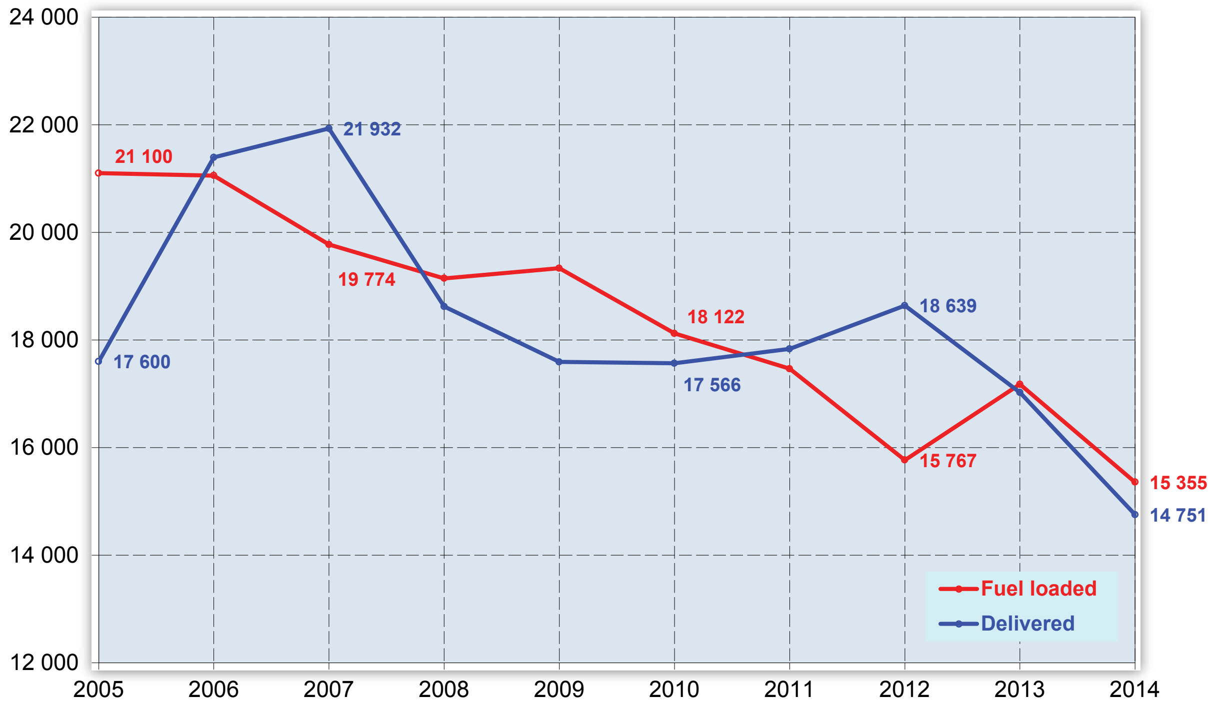
(1) Multiannual contracts are contracts providing for deliveries extending over more than 12 months, whereas spot contracts provide either for one delivery only or for deliveries over a maximum of 12 months, whatever the time between conclusion of the contract and the first delivery.

(2) Purchase/sale contracts between intermediaries — neither the buyers nor the sellers are EU utilities/end-users.

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

(4) In addition, there were transactions for small quantities (Article 74 of the Euratom Treaty) which are not included here.

**Figure 4:** Natural uranium feed contained in fuel loaded into EU reactors and natural uranium delivered to utilities under purchasing contracts (tU)



### *Volume of deliveries*

The deliveries taken into account are those to EU utilities or their procurement organisations in 2014, excluding research reactors. Also taken into account is the natural uranium equivalent contained in enriched uranium purchases, when stated.

In 2014, demand for natural uranium in the EU represented approximately one third of global uranium requirements. EU utilities purchased a total of 14 751 tU in 125 deliveries under long-term and spot contracts, 2 272 tU or 13.4 % less than in 2013. As in previous years, long-term supplies constituted the main source for meeting demand in the EU. Deliveries of natural uranium to EU utilities under long-term contracts accounted for 14 238 tU (of which 13 508 tU were with reported prices) or 96.5 % of the total deliveries, whereas the remaining 3.5 % (513 tU) was purchased under spot contracts. On average, the quantity of natural uranium delivered was 125 tU per delivery under long-term contracts and 50 tU per delivery under spot contracts.

Natural uranium contained in the fuel loaded into reactors in 2014 totalled 15 355 tU. The difference between natural uranium delivered and natural uranium contained in the fuel loaded was negative. Quantities of natural uranium feed contained in fuel loaded into EU reactors and natural uranium delivered to utilities under purchasing contracts are shown in Figure 4 (see Annex 2 for the corresponding table for 1980-2014).

### *Average prices of deliveries*

In order to enhance market transparency, ESA publishes annually three EU natural uranium price indices, which 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 using sophisticated 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 (ECB), into EUR/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 — Calculation method for ESA's average $U_3O_8$ prices.

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 2014 amounted to 1.33, the same as in the previous year.

In order to establish a natural uranium price excluding the conversion cost, whenever the latter was included but not specified, ESA applied a rigorously calculated average conversion price, on the basis of reported conversion prices under the natural uranium long-term contracts.

| 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 2014 was calculated as: | |
|---|---|
| **EUR 74.65**/kgU contained in $U_3O_8$ | (5 % down from EUR 78.24/kgU in 2013) |
| **USD 38.15**/lb $U_3O_8$ | (5 % down from USD 39.97/lb $U_3O_8$ in 2013) |

| 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 2014 was calculated as: | |
|---|---|
| **EUR 78.31**/kgU contained in $U_3O_8$ | (8 % down from EUR 85.19/kgU in 2013) |
| **USD 40.02**/lb $U_3O_8$ | (8 % down from USD 43.52/lb $U_3O_8$ in 2013) |

| 3. ESA 'MAC-3' new 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 three years and under which deliveries were made in 2014, was calculated as: | |
|---|---|
| **EUR 93.68**/kgU contained in $U_3O_8$ | (11 % up from EUR 84.66/kgU in 2013) |
| **USD 47.87**/lb $U_3O_8$ | (11 % up from USD 43.25/lb $U_3O_8$ in 2013) |

The ESA $U_3O_8$ spot price reflects the latest developments on the uranium market as it is calculated from contracts providing either for one delivery only or for deliveries over a maximum of 12 months. In 2014, the ESA $U_3O_8$ spot price was EUR 74.65/kgU (or USD 38.15/lb $U_3O_8$), 5 % lower than in 2013. Price data were widely distributed, mostly falling within the range of EUR 65.92 to EUR 96.35/kgU (USD 33.68 to USD 49.22/lb $U_3O_8$). For the second time in 10 years, ESA's spot price in 2014 was lower than its long-term price.

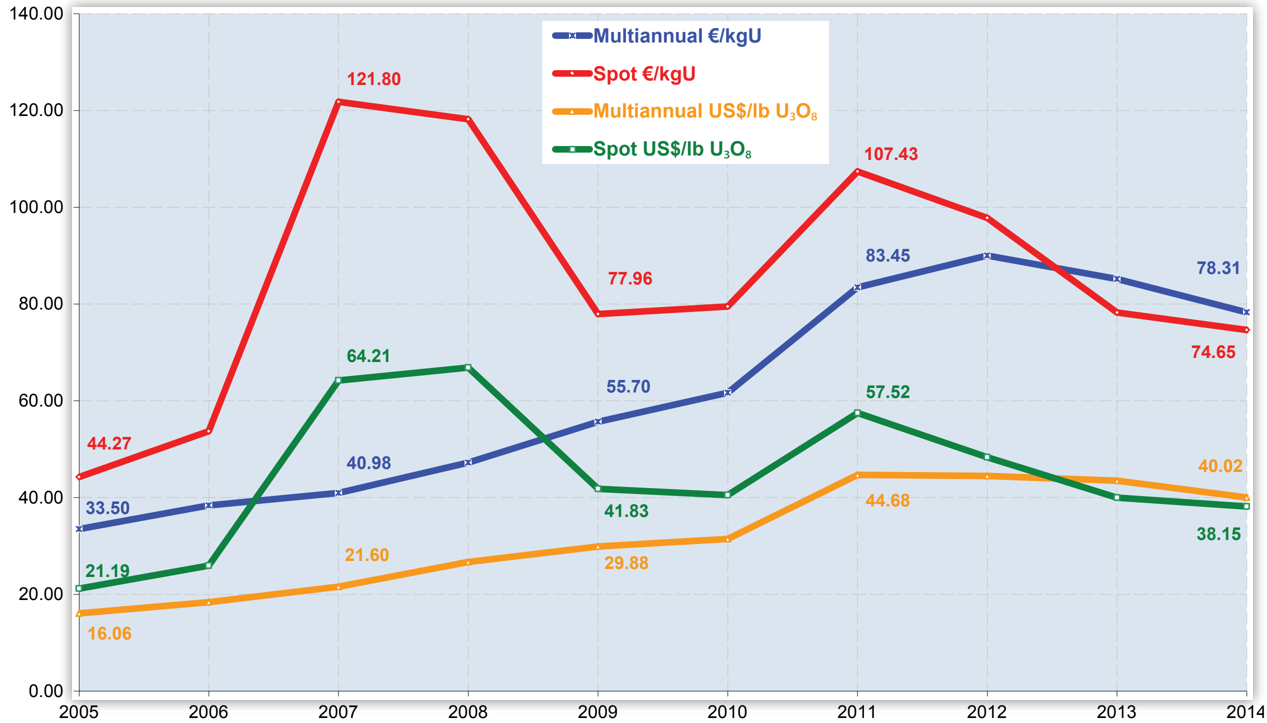
The ESA long-term $U_3O_8$ price was EUR 78.31/kgU $U_3O_8$ (USD 40.02/lb $U_3O_8$). Long-term prices paid varied widely, with approximately 75 % (assuming a normal distribution) falling within the range of EUR 65.96 to EUR 107.18/kgU (USD 33.70 to USD 54.77/lb $U_3O_8$). Normally, traded long-term prices go 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 2014 had been signed eight years earlier. The ESA long-term $U_3O_8$ price paid for uranium originating in the Commonwealth of Independent States (CIS) was approximately 8 % lower than the price for uranium of non-CIS origin.

ESA MAC-3 multiannual $U_3O_8$ price data were spread across a wide range, with approximately 80 % of prices reported as falling between EUR 75.86 and EUR 110.55/kgU (USD 38.77 to USD 56.49/lb $U_3O_8$). The ESA MAC-3 index takes into account only long-term contracts signed recently (2012-14) 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 27 % lower than the price for uranium of non-CIS origin.

Figure 5 shows ESA average prices for natural uranium since 2005. The corresponding data are presented in Annex 3.

**Figure 5:** Average prices for natural uranium delivered under spot and multiannual contracts, 2005-14 (EUR/kgU and USD/lb $U_3O_8$)




## *Origins*

In 2014, natural uranium supplies to the EU continued to come from diverse sources. In general, the origins of natural uranium supplied to EU utilities were the same as in 2013. With regard to four big uranium-producing regions (the CIS, North America, Africa and Australia), deliveries from all of them decreased in 2014, particularly from North America and Africa, while deliveries from the CIS and Australia dropped slightly.

Kazakhstan retained first place and Russia replaced Canada in second place among the biggest suppliers, compared with the previous year. The top two countries delivered to the EU natural uranium accounting for 45 % of the total. Uranium originating in Kazakhstan represented the largest proportion, with 3 941 tU or 27 % of total deliveries, which was more than 9 % up on 2013. It was followed by uranium of Russian origin, with an 18 % share or 2 649 tU (including purchases of natural uranium contained in EUP), a year-on-year decline of 14 %. In third place, uranium mined in Niger amounted to 2 171 tU or 15 %, a 3 % decrease from 2013. Australia and Canada accounted for 14 % and 13 % in 2014, a decrease of 1 % and 41 %, respectively.

Natural uranium mined in the CIS (Kazakhstan, Russia, Usbekistan and Ukraine) accounted for 6 978 tU, or approximately 47 % of all natural uranium delivered to EU utilities, a 5 % decrease from the year before.

Deliveries of uranium of North American origin totalled 2 442 tU (16.6 %), a decrease of 31 % from 2013. Uranium of Canadian origin accounted for 1 855 tU (12.6 %).

Deliveries of uranium from Africa decreased by more than 14 %, down to 2 641 tU from 3 084 tU in 2014. Uranium extracted from Niger accounted for 82 % of all African-origin uranium. A substantial decrease was reported in deliveries of uranium extracted in Namibia, whereas deliveries of uranium extracted in Malawi and South Africa reported modest increase.

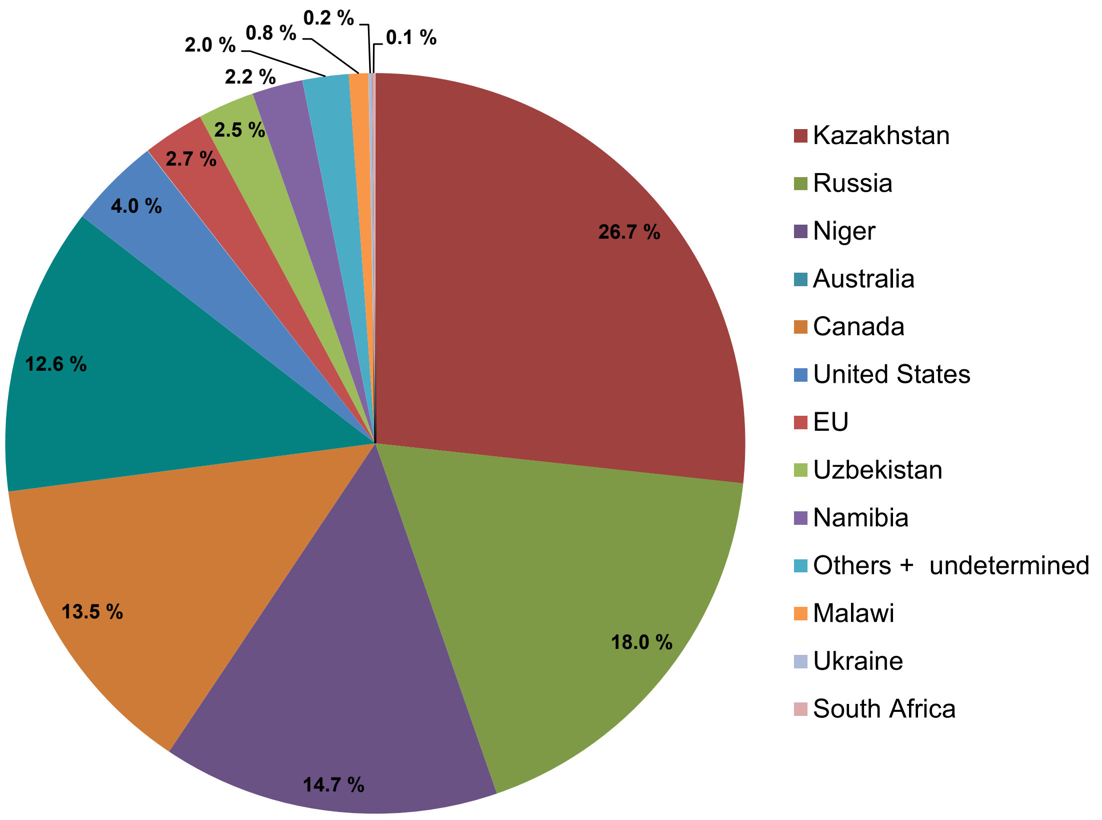
Australian-origin uranium totalled 1 994 tU. European uranium delivered to EU utilities originating from the Czech Republic and Romania covered 2.7 % of the EU's total requirements (a total of 397 tU), which is about 6 % down compared to 2013.

Small deliveries of re-enriched tails (RET) material were reported by EU utilities.

Table 7: Origins of uranium delivered to EU utilities, 2014 (in tonnes)

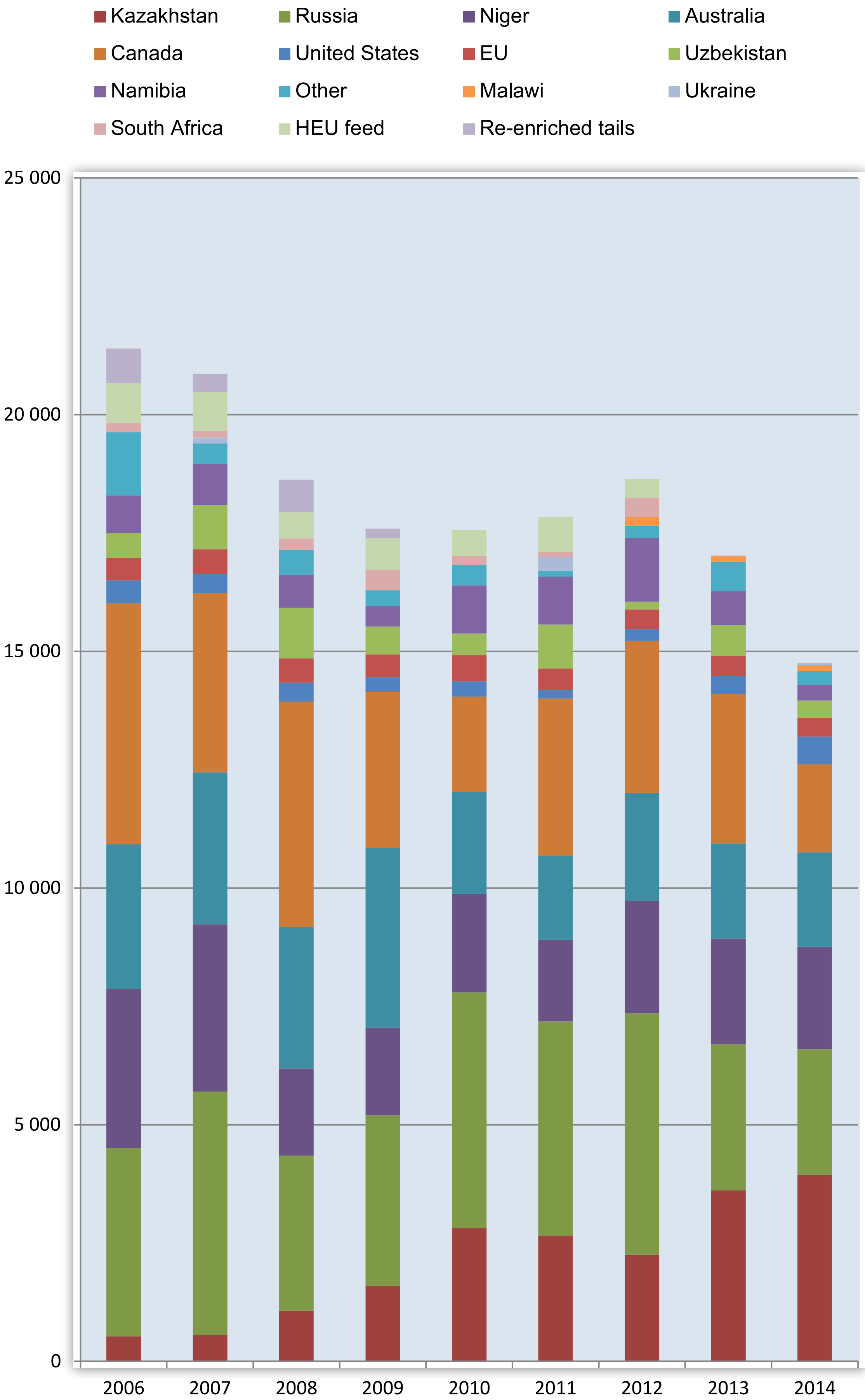
| Mining origin | Quantity | Share (%) | Change 2014/13 (%) |
|---|---|---|---|
| Kazakhstan | 3 941 | 26.7 | 9.1 |
| Russia | 2 649 | 18.0 | – 14.1 |
| Niger | 2 171 | 14.7 | – 2.9 |
| Australia | 1 994 | 13.5 | – 0.8 |
| Canada | 1 855 | 12.6 | – 41.2 |
| US | 586 | 4.0 | 54.1 |
| EU | 397 | 2.7 | – 5.8 |
| Uzbekistan | 365 | 2.5 | – 44.1 |
| Namibia | 325 | 2.2 | -54.6 |
| Other | 299 | 2.0 | – 51.9 |
| Malawi | 125 | 0.8 | 8.0 |
| Ukraine | 23 | 0.2 | 100 |
| South Africa | 20 | 0.1 | 17.7 |
| **Total** | **14 751** | **100** | **– 13.4** |

Figure 6: Origins of uranium delivered to EU utilities, 2014 (% share)




NB: Totals may not add up due to rounding.

**Figure 7:** Purchases of natural uranium by EU utilities by origin, 2006-14 (tU)



## Special fissile materials

### *Conclusion of contracts*

Table 8 shows the aggregate number of contracts, notifications and amendments ([23]) relating to special fissile materials (enrichment services, enriched uranium and plutonium) dealt with in 2013 and 2014 in accordance with ESA's procedures.

### *Deliveries of low-enriched uranium*

In 2014, the enrichment services (separative work) supplied to EU utilities totalled 12 524 tSW, delivered in 2 048 tonnes of low-enriched uranium (tLEU) which contained the equivalent of 16 139 tonnes of natural uranium feed. In 2014, enrichment service deliveries to EU utilities increased by 7 % as compared with 2013, with NPP operators opting for an average enrichment assay of 4.09 % and an average tails assay of 0.24 %.

**Table 8:** Special fissile material contracts concluded by or notified to ESA

| Type of contract | Number of contracts concluded/ notifications acknowledged in 2014 | Number of contracts concluded/ notifications acknowledged in 2013 |
|---|---|---|
| **A. Special fissile materials** | | |
| **New contracts** | **29** | **42** |
| Purchase (by an EU utility/user) | 6 | 7 |
| Sale (by an EU utility/user) | 5 | 9 |
| Purchase/sale (between two EU utilities/users) | 4 | 2 |
| Purchase/sale (intermediaries) | 9 | 20 |
| Exchanges | 5 | 2 |
| Loans | 0 | 2 |
| **Contract amendments** | **36** | **25** |
| **Total (1)** | **65** | **67** |
| **B. Enrichment notifications (2)** | | |
| **New notifications** | 11 | **1** |
| **Notifications of amendments** | **5** | **12** |
| **Total** | **16** | **13** |

(1) In addition, there were transactions for small quantities (Article 74 of the Euratom Treaty) which are not included here.
(2) Contracts with primary enrichers only.

**Table 9:** Providers of enrichment services delivered to EU utilities

| Enricher | Quantities in 2014 (tSW) | Share in 2014 (%) | Quantities in 2013 (tSW) | Share in 2013 (%) | Change in quantities 2014/13 (%) |
|---|---|---|---|---|---|
| AREVA/GBII and Urenco (EU) | 8 503 | 68 | 6 956 | 60 | 22 |
| Tenex/TVEL (Russia) | 3 197 | 26 | 4 249 | 36 | – 25 |
| USEC (US) | 200 | 2 | 354 | 3 | – 44 |
| Others (1) | 624 | 5 | 119 | 1 | 423 |
| **Total (2)** | 12 524 | 100 | 11 678 | 100 | 7 |

(1) Including enriched reprocessed uranium.
(2) Totals may not add up due to rounding.

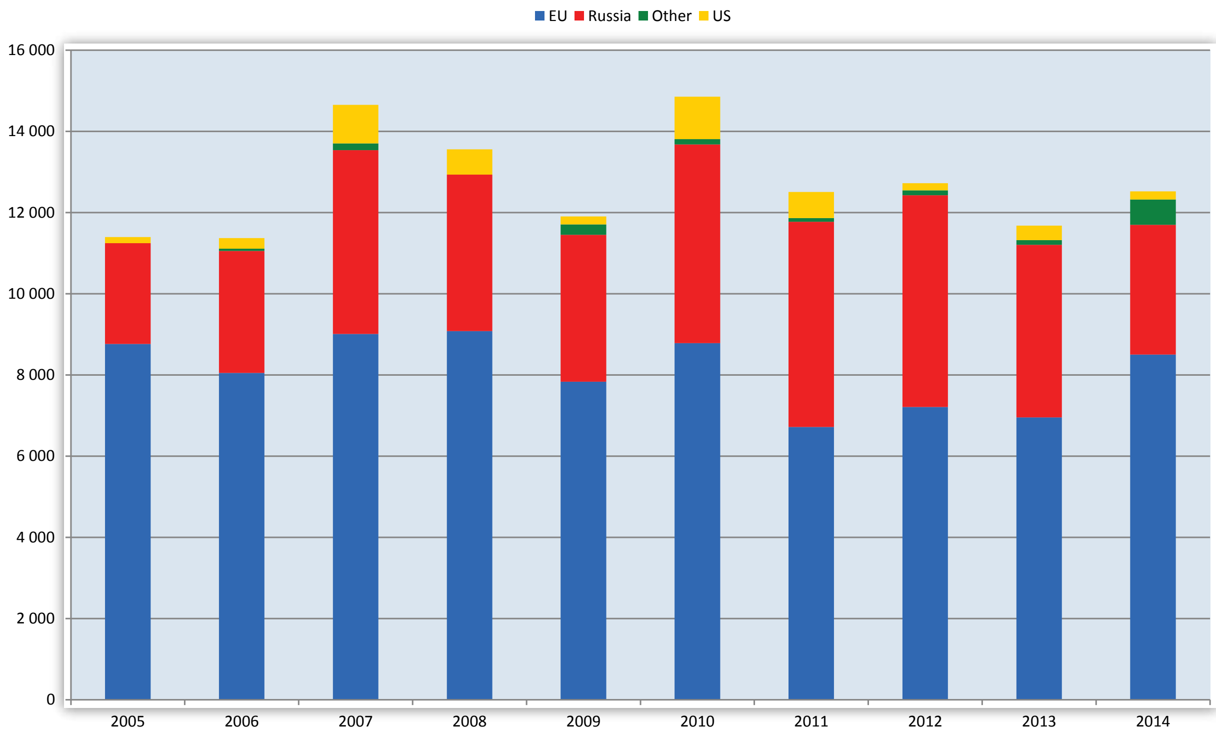
(23) The aggregate number of amendments includes all the amendments to existing contracts processed by ESA, including technical amendments that do not necessarily lead to substantial changes in the terms of existing agreements.

As regards the providers of enrichment services, 68 % of the EU requirements were met by the two European enrichers (AREVA-GBII and Urenco), totalling 8 503 tSW, which was an increase of 8 percentage points in market share year on year.

Deliveries of separative work from Russia (Tenex and TVEL) to EU utilities under purchasing contracts totalled 3 197 tSW, a decrease of 10 % in market share compared with 2013. The aggregate total includes SWUs delivered under contracts 'grandfathered' under Article 105 of the Euratom Treaty, which covered 7 % of total requirements in the EU. The fuel supply contracts concluded before accession to the EU remained in force. Russian enrichment services delivered under regular contracts accounted for 19 % of total requirements.

Enrichment services provided by USEC decreased in 2014, totalling 200 tSW and accounting for 2 % of the total enrichment services supplied to EU utilities.

**Figure 8:** Supply of enrichment to EU utilities by provider, 2005-14 (tSW)




### *Plutonium and mixed-oxide 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 measures, so reactors have to be adapted for this kind of fuel and obtain a 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 MOX fuel 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 MOX fuel loaded into NPPs in the EU totalled 11 603 kg Pu in 2014, a 4 % increase over the 11 120 kg Pu used in 2013.

### *Inventories*

Uranium inventories owned by EU utilities at the end of 2014 totalled 52 898 tU, a decrease of 3 % from the end of 2013 and an increase of 15 % from the end of 2009. 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 foreign nuclear facilities.

**Figure 9:** Total uranium inventories owned by EU utilities at the end of the year, 2009-14 (tU)

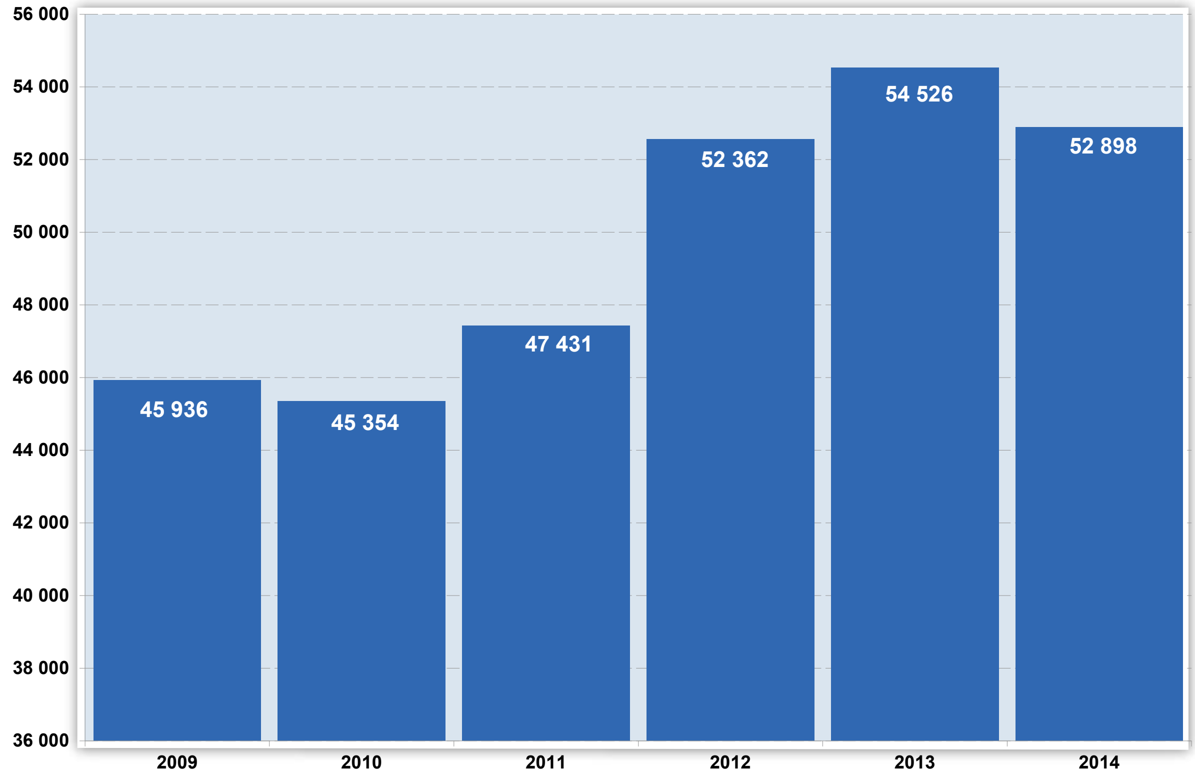



Figure 9 shows the level of total uranium inventories owned by EU utilities at the end of the year, expressed as natural uranium equivalent.

The dynamics of 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 17 000 tU/year), uranium inventories can fuel EU utilities' nuclear power reactors, on average, for 3 years, ranging from 6 months to 5.5 years. The majority of 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 10 shows the contractual coverage rate for natural uranium and SWUs for EU utilities.

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

As regards net reactor requirements (denominator), a distinction is made between demand for natural uranium and demand for enrichment services. Average net reactor requirements for the period 2015-24 are estimated at approximately 15 700 tU and 13 300 tSW per year, respectively (see Figure 3).

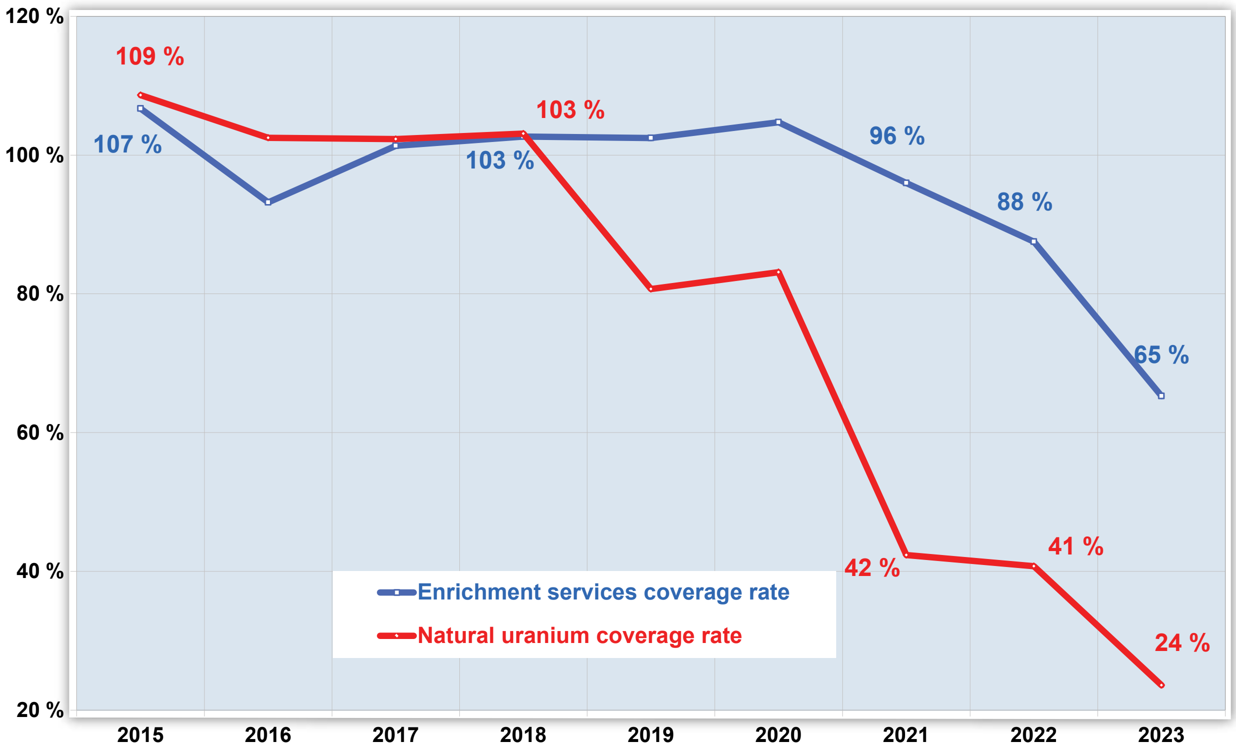
Quantitative analysis shows that EU utilities are covered well above their estimated net reactor requirements (about 100 %) until 2018, in terms of both natural uranium and enrichment services, under already-signed contracts.

Natural uranium coverage: Supply of natural uranium is fully guaranteed from 2015 to 2018 with a contractual coverage rate of slightly over 100 %. In the long term, the uranium coverage rate will remain above 80 % until 2020, dropping to around 40 % in 2021.

SWU coverage: Enrichment services supply is well secured until 2022, with contractual coverage ranging from 88 % to 107 %, dropping to 65 % in the last year of the analysis.

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

Figure 10: Coverage rate for natural uranium and enrichment services, 2015-23 (%)




## ESA findings, recommendations and diversification policy

Each year ESA continues to monitor the market, especially supplies of natural and enriched uranium to the EU, in order to ensure that EU utilities have diverse sources of supply and do not become over-dependent on any single source. It does this by exercising its right to sign contracts and by compiling comprehensive statistical reports on trends on the nuclear market. 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.

ESA recommends that utilities cover most of their current and future requirements for natural uranium and enrichment services 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, in 2014, for 96.5 % of total deliveries. As regards mining origin, the relative shares of individual producer countries changed in comparison with the previous year, with Kazakhstan, Russia, Niger, Australia and Canada together providing 85 % of the natural uranium delivered to the EU. In 2014, uranium deliveries originating from North America and Africa decreased by 31 % and 14 % respectively. There was also a decrease in deliveries of uranium of CIS and Australian origin (down 5 % and 1 % respectively), while EU-origin deliveries dropped by 6 % compared with the previous year. Overall, the deliveries of natural uranium to EU utilities are well diversified, but there are some utilities buying their natural uranium from only one supplier.

Regarding the diversification of sources of supply of enriched uranium to EU utilities, 68 % of the SWUs delivered in 2014 were provided by the two European enrichment companies, AREVA-GBII and Urenco. The remaining services were delivered mostly by Russia's Tenex/TVEL (26 %), and by the US company USEC (2 %), which emerged after reorganisation in 2013 as Centrus Energy Corporation and sells Russian-origin SWUs.

In 2014, deliveries of enrichment services increased by 7 % and the two European enrichers increased their relative share in the EU market. Out of the 26 % of Russian-origin SWUs, contracts 'grandfathered' under Article 105 of the Euratom Treaty accounted for 7 % of total deliveries. In practice, 'grandfathered' contracts keep certain EU utilities entirely dependent on a single external supplier ([24]).

ESA welcomes the use of RepU, either by downblending HEU to produce power-reactor-grade fuel or by its re-enrichment (in Russia), on the basis that such practices increase security of supply. Furthermore, blending RepU 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 downblended with RepU and re-enriched reprocessed uranium fuel accounted for the equivalent of approximately 7 % of the total enrichment services delivered in 2014.

([24]) The significant differences in supply patterns and, therefore, in the diversification of sources of supply are due to the fact that utilities with western technology traditionally obtain uranium and services (e.g. enrichment) under separate contracts from diverse ources, whereas utilities using Russian technology usually purchase fabricated fuel assemblies from a single supplier under the same contract (including supply of uranium and enrichment).

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 2014 totalled 52 898 tU, which could fuel EU utilities' nuclear power reactors, on average, for 3 years. However, the average conceals a wide range, and some utilities would be wise to consider increasing their stocks.

On the supply side, ESA monitors the situation of EU producers which export nuclear material mined 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 under long-term contracts, ESA requires 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 2014, 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, there is a concern over the 100 % reliance on one single supplier for VVER fuel fabrication.

# 4. Security of supply

## Introduction

The market for uranium and fuel cycle services is a global market, albeit smaller and less liquid than oil and gas markets, meaning that prices could spike rapidly in the event of supply problems. However, the cost of uranium and of nuclear fuel generally is only a small part of the operating costs of a nuclear power plant (5-10 %), so that even a sharp increase in fuel prices would not lead to a big change in the final electricity price. Therefore, the main issue for the industry is availability of fuel and avoiding any disruptions in supply.

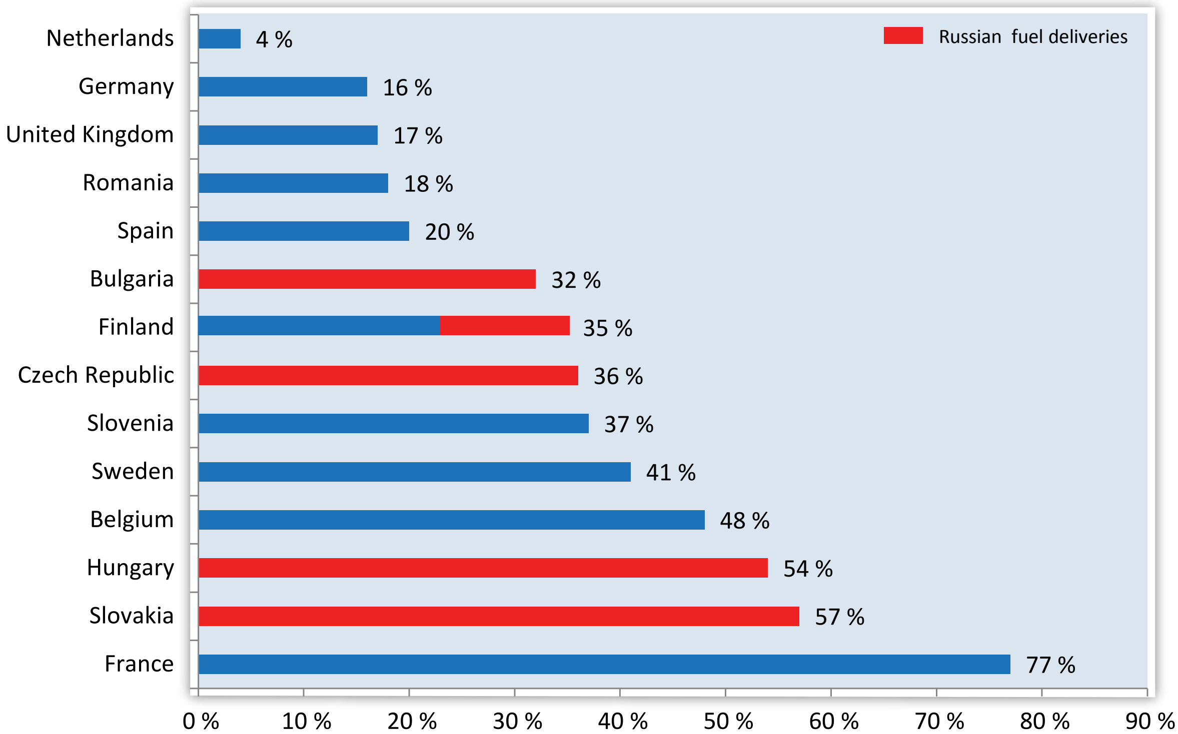
## Security of supply and ESA's diversification policy

ESA continues to monitor the market in order to ensure that EU utilities have diverse sources of supply and do not become over-dependent on any single source which could jeopardise security of supply in the medium and long term, for technical or political reasons. It does this by exercising its right to sign contracts and by compiling comprehensive statistical reports on trends on the nuclear market. 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 EU utilities are 100 % dependent on one external supplier. In these cases, the share of nuclear in the energy mix of those Member States and their potential electricity exports to neighbouring Member States must be taken into account, in order to evaluate the overall risk for stable electricity supplies.

In its market-monitoring role, ESA has responsibility for early identification of market trends likely to affect medium- and long-term security of supply of nuclear materials and services in the EU, both at aggregate EU level and in the case of individual utilities. In the event of such trends being detected, the Agency would consider relevant remedial action.

Figure 11:Nuclear power share of total electricity production in the EU, 2014 (%)



In the event of a sudden deterioration of the situation in the market requiring a quick reaction (in particular, if external dependence increases significantly in a short period of time or if imports risk distorting competition within the EU internal market), or if a user fails to diversify its sources of supply or to implement remedial measures, ESA must make use of its powers under Chapter 6 of the Treaty.

The European Energy Security Strategy communication published in May 2014 ([25]) highlighted the role of nuclear fuels and strengthened the ESA mandate by providing that '… particular attention should be paid to investments in new nuclear power plants to be built in the EU using non-EU technology, to ensure that these plants are not dependent only on Russia for the supply of the nuclear fuel: the possibility of fuel supply diversification needs to be a condition for any new investment, to be ensured by the Euratom Supply Agency. Furthermore, an overall diversified portfolio of fuel supply is needed for all plant operators.'

Over the past year, the ESA Advisory Committee working group on prices and security of supply revised an earlier ESA Advisory Committee study on security of supply. The goal of the working group was to provide an updated analysis of nuclear fuel availability at EU level. A general conclusion of the final report is that the security of supply of nuclear fuel to EU utilities is well maintained, but there are aspects which could be improved and the global market situation should be carefully monitored. The main findings of this report (which is published separately) are reflected in this chapter.

## Supply side — assessment of the global situation

Natural uranium is produced in many regions of the world and production has increased in recent years although it still does not cover global reactor requirements (the balance is covered by secondary sources of supply — HEU downblending, RepU and Pu use in MOX fuel, underfeeding, tails re-enrichment). When global demand recovers to the level prevailing before the Fukushima accident, or if a supply problem arises somewhere, other producers could fill the gap. During the commodity boom between 2004 and 2008, a lot of exploration was carried out and identified uranium reserves have increased but are not being developed due to currently low prices.

Conversion remains a critical step in the nuclear fuel cycle and therefore, in order to ensure that $UF_6$ production will meet the demand and cover the estimated future gap in the supply–demand balance, primary converters should continue to take measures to increase capacity utilisation at existing plants, build new capacity and/or prolong the operating lifetime of present facilities.

For enrichment, the current global commercial nameplate capacity of over 56 000 tSW is considered to be sufficient to cover demand at least until 2020.

The existing fuel fabrication capacity, ensured by several reliable PWR/BWR/CANDU-type fuel fabricators, is considered more than sufficient to meet current demand, including projected first core loads, well into the 2020s. However, with regard to VVER-type reactors, the closed nature of this market segment raises concerns for future security of supply.

## 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 is limited, EU companies have mining operations in several major producer countries. Resources of natural uranium located in different Member States could be considered as a potential source of supply, at least from a long-term perspective.

In addition, there is considerable potential for increasing the use of RepU and plutonium in the EU, should natural uranium prices rise. 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 in the event of a shortage. Currently, 12.5 % of the nuclear material used in fuel loaded comes from indigenous sources (see Table 5). These operations could be performed by EU industry.

For other parts of the fuel cycle (conversion, enrichment, fuel fabrication and spent fuel reprocessing), EU industry can cover most or all of the EU utilities' needs. It is also possible to expand capacity according to demand, albeit not very quickly. The main challenge is to ensure the EU industry's continued viability so that the current industrial capacity and technological level are at least maintained and do not diminish as a result of short-term economic considerations.

While the EU's uranium conversion capacity is concentrated in France, enrichment plants operate in France, Germany, the Netherlands and the United Kingdom. Likewise, fabrication plants are located in many Member States, although each is dedicated to producing only certain types of fuel. The capacity to produce fuel and components for VVER reactors in the EU is an important aspect which needs further attention.

## Demand side — assessment of the EU situation

In the EU, there are two distinct nuclear fuel procurement approaches: utilities operating western-design reactors usually enter into separate contracts with uranium mining companies, conversion service providers, enrichment service providers and finally fuel assembly manufacturers. This approach allows for diversification of all steps of the front end of the fuel cycle, and for bigger utilities it offers the possibility to maintain several suppliers at all stages. Nuclear materials and fuel cycle services, other than fabrication, may be quite easily substituted by other sources in current market conditions.

In contrast, utilities operating Russian-design reactors in most cases purchase their fuel as integrated packages of fuel assemblies, including the uranium and related services, from the same Russian supplier.

Natural uranium is sufficiently available in the market and natural uranium supplies to the EU are well diversified. Furthermore, a number of key supplier countries are politically stable

([25]) COM(2014) 0330 final, 28.5.2014.

and have cooperation agreements with the EU. The situation does not raise concerns of shortage in the medium term.

In the 'western world' there are three suppliers of conversion services, two in North America and one in the EU (France). Combined with other services, conversion is also provided by the Russian industry. As long as all of them are in operation, there should be no shortage of supply of this service.

Enrichment is the most sensitive operation, due to the confidentiality of the technology used, the related nuclear non-proliferation aspects, and its commercial importance within the fuel cycle. As for conversion, the market is oligopolistic, currently divided between Urenco (EU), Areva (EU) and Tenex/TVEL (Russia). The Russian share of the EU market has been around 40 % in recent years.

For fuel fabrication, the situation is different since fuel assemblies are reactor specific and dependent on the reactor design. While operators with western-design reactors usually have the choice between two or even three different fuel fabricators, four countries, namely Bulgaria, Czech Republic, Hungary and Slovakia, operating exclusively VVER reactors are presently 100 % dependent on Russian suppliers of fuel assemblies. Additionally, two out of the four operating reactors in Finland are of VVER-type, which represents 36 % of the country's nuclear electricity production. The dependence on one single supplier constitutes a risk, since qualifying an alternative supplier would take several years due to licensing and testing requirements before commercial use. Some of the VVER operating utilities have started purchasing part of their EUP requirements from other market sources, which is a useful first step towards full diversification.

### *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 for 1 or 2 years' operation in different forms (natural or enriched uranium, fabricated fuel assemblies). Some utilities are covered for more than 4 years, others only for some months. In the current situation, the most vulnerable utilities in terms of security of supply are those that depend on Russian fabricated fuel assemblies (VVER reactors), which cannot be quickly replaced by fuel assemblies from another manufacturer.

While some utilities have been selling what may previously have been excessive inventories, others would be wise to consider increasing their stocks.

In 2014, ESA conducted a survey among EU Member States that have NPPs in operation, to identify which ones have legal provisions governing strategic stocks of nuclear fuel or materials. The outcome was that roughly half of those Member States have legal requirements concerning stocks, albeit often not very detailed. In the others, utilities are entirely free to implement their own strategic stock policy.

## ESA findings and recommendations

Following thorough analysis of the information gathered from EU utilities at the end of 2014 (as indicated in chapter 3), ESA concludes that, in the short and medium term, the needs of EU utilities for both natural uranium and enrichment services are 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 also recommends that EU utilities maintain adequate strategic inventories of nuclear materials and use market opportunities to increase their stocks, depending on their individual circumstances. In order to forestall risks of shortages in the nuclear fuel supply chain, appropriate levels of inventories should be maintained not only by EU utilities but also producers.

As regards fuel fabrication, there is concern over the 100 % reliance on one single supplier for VVER reactors in the EU. In practice, 'grandfathered' contracts (concluded before a country joins the EU) keep certain EU utilities dependent on a single external supplier, although some of these contracts include an option to purchase nuclear materials from alternative sources.

From a security of supply point of view, there should always be at least two alternative suppliers for each stage of the fuel cycle, including fuel assemblies licensed for each reactor. 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 their other electricity generation assets.

For bundled sales of fuel assemblies (i.e. including nuclear material, conversion, enrichment and fuel fabrication), the supplier of fuel assemblies must allow the operator to purchase natural or enriched uranium from other sources as well. In particular for new reactors, the reactor constructor must enable the use of fuel assemblies produced by different fabricators by disclosing fuel compatibility data and allowing the testing of alternative fuel assemblies. Operators should ensure that fuel supply diversification is possible for their reactors at all stages of the fuel cycle.

If an alternative fuel fabricator is not yet available, contacts should be established with potential fabricators interested in developing the required fuel. In such situations, testing of alternative fuel elements can be started with lead-test assemblies. Both operators and national regulators of countries operating VVER reactors could benefit from cooperation in the development, testing and licensing of 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 and further develop their technology and continue to invest in upgrading their production facilities to the extent possible under the prevailing market conditions.

# 5. Supply of medical radioisotopes

### *ESA involvement*

The Observatory role of ESA was widened in 2013 to cover aspects of the supply of medical radioisotopes in the EU, in the light of Council conclusions, 'Towards the secure supply of radioisotopes for medical use in the EU', dated 2010 ([26]) and 2012 ([27]), prepared in response to the increased fragility of the current production chain, which relies on an unsustainably low number of ageing research reactors, and in an effort to obtain the necessary supplies of nuclear material for uranium targets used for radioisotope production.

In 2014, ESA continued coordinating European Commission activities undertaken to improve the security of supply of Molybdenum-99/Technetium-99m (Mo-99/Tc-99m — the most vital medical radioisotope), and chaired the European Observatory on the supply of medical radioisotopes ([28]), which was set up in 2012.

### *European Observatory on the supply of medical radioisotopes*

The Observatory seeks to gather all relevant information to assist the decision-makers of the EU institutions and national governments in defining strategies as well as policies for their implementation. The Observatory has four general strategic objectives: to support secure Mo-99/Tc-99m supply across the EU; to ensure that the issue of Mo-99/Tc-99m supply is given high political visibility; to encourage the creation of a sustainable economic structure of the supply chain; and to establish periodic reviews of the supply capacities and demand. The Observatory is composed of members from the EU institutions and various industry stakeholders, most of which are grouped within the AIPES (Association of Imaging Producers and Equipment Suppliers) ([29]). It functions through four working groups: 1 — Global reactor scheduling and Mo-99 supply monitoring; 2 — Full-cost recovery mechanisms; 3 — Management of HEU–LEU conversion and target production; and 4 — Capacity and infrastructure development.

In 2014, two plenary meetings of the Observatory were held in Paris (in January and July), at which the reports prepared by the working groups were discussed.

### *Working Group 1 — Global reactor scheduling and Mo-99 supply monitoring*

Working Group 1 (WG1) ensures effective coordination of reactor schedules to avoid and mitigate Mo-99 supply disruptions and has established for this purpose an emergency response team (ERT), composed of representatives from research reactors, Mo-99 processors and Mo-99/Tc-99m generator manufacturers. In November 2013, the ERT was activated due to extended shutdown of the HFR reactor, lasting until February 2014, and temporary closure of the Mo-99 production facility in Petten (the Netherlands) until April 2014. In order to keep supply at the maximum possible level, the ERT convened a series of meetings during this period to discuss and implement all possible mitigation actions to avoid severe shortages. All European research reactor operators and their staff, with the continuous support of radioisotope processors, generator manufacturers and service providers such as transport companies, have worked remarkably well together to coordinate and ensure the necessary continuity of medical radioisotope production for the medical community. Non-European research reactors and processors have also been heavily involved in this process.

Another important measure taken by WG1 in 2014 entailed the establishment of a joint communication team, aiming at providing prompt communication to governments in case of supply interruptions. The communication protocol and news release template were agreed between the Observatory's members. In the event of future supply shortages, the governmental representatives of the EU Member States will be informed via ESA through the Council's working group on atomic questions and via the Directorate-General for Health through the Health Security Committee ([30]). The latter is a cooperation and coordination body concentrating on health-related threats and is the key mechanism for coordinating health security efforts at EU level, established under Decision No 1082/2013/

([26]) http://ec.europa.eu/euratom/docs/118234.pdf
([27]) http://ec.europa.eu/euratom/docs/2012_council_radioisotopes.pdf
([28]) http://ec.europa.eu/euratom/observatory_radioisotopes.html
([29]) http://www.aipes-eeig.org

([30]) http://ec.europa.eu/health/preparedness_response/risk_management/hsc/index_en.htm

EU of the European Parliament and of the Council of 22 October 2013 ([31]).

## *Working Group 2 — Full-cost recovery mechanisms*

One of the key principles of the OECD/NEA HLG-MR ([32]) policy approach is that all Mo-99/Tc-99m supply chain participants should implement full-cost recovery (FCR). This would provide the economic incentives to develop Mo-99-related infrastructures and to fully finance operating costs. For a consistent approach on how costs are identified, the HLG-MR developed a methodology which identifies the essential elements that should be included when determining the full cost of Mo-99 irradiation services, including a reasonable portion of facility common costs, and how these elements should be allocated between various missions in the case of multipurpose facilities.

Within the Observatory, the issue of FCR is dealt with by WG2. To facilitate discussions on this subject in the EU, WG2 organised a European Workshop on FCR for all European reactor operators and processors and key ministry officials responsible for health, economy and research reactors in the EU Member States; it was held in Luxembourg in September 2013, and provided an opportunity to discuss the next steps in the process of implementing FCR in Europe.

During the workshop it was agreed that the possibility of devising a timeline for implementing FCR through an intergovernmental agreement would be analysed with the EU countries supplying irradiation services. A dedicated meeting of the governmental representatives from these countries was organised and hosted by the Dutch Ministry of Economic Affairs in March 2014 in The Hague, at which a draft joint political statement on possible initiatives for sustainable medical radioisotopes supply in Europe was discussed. Due to the complexity of this subject, agreement on the text was not reached at the meeting; however, participants shared an overarching interest in improving the security of supply and agreed to work further on a joint political statement, with the long-term goal being to propose a consistent European policy approach. A new draft statement was subsequently tabled by the Dutch ministry, and a technical working group, in which all the abovementioned countries are involved, was set up. Discussions in the working group are ongoing with the aim of finalising the work on the document as soon as possible.

## *Working Group 3 — Management of HEU–LEU conversion and target production*

In addition to addressing the ongoing concerns related to long-term reliability of the medical radioisotope supply chain, all current producing countries have agreed to the principle of converting to using LEU targets for Mo-99 production under the work plan of the 2010 Washington Nuclear Security Summit based on important nuclear security reasons originally expressed in the framework of the Global Threat Reduction Initiative (GTRI). However, such a conversion, being externally imposed on the market players, will have an impact on the global supply chain — both in terms of costs (including a larger volume of radioactive waste) and as regards available capacity (LEU target conversion does reduce the available irradiation and processing capacity).

In this context, the radioisotope processors within the EU are making progress in converting to non-HEU-based methods. As this is a technically and economically challenging operation it is very important to secure the continuity of supply of Mo-99 throughout the process of conversion.

Working Group 3 (WG3) has undertaken a study of the risks that could occur during the HEU–LEU conversion of targets used for radioisotope production. The group developed a generic description of the production process, then identified each of the risks that could arise, followed by assessment of the potential impact. Finally, potential mitigating actions were determined, including recommendations for the radiopharmaceutical industry and policymakers ([33]).

Also, WG3 has liaised with the European Medicines Agency (EMA) ([34]) on the subject of authorisation of a new LEU-based Mo-99 by the drug regulatory agencies. The option of 'grouping and worksharing' (Articles 7 and 20 of Regulation (EC) No 1234/2008 as amended by Regulation (EU) No 712/2012) ([35]), which could potentially accelerate authorisation of a new LEU-based Mo-99 in the EU, was explained to the European stakeholders at the July 2014 plenary meeting of the Observatory, including the regulatory framework and timelines for the approval process for variations to national marketing authorisations via the Coordination Group for Mutual Recognition and Decentralised Procedures — human (CMDh) ([36]).

The importance of the HEU–LEU conversion of irradiation targets was highlighted in the corresponding Council conclusions, adopted in 2012, which called upon the European Commission to propose to Member States a relevant instrument to provide Community support for the conversion of HEU to LEU targets and to identify the needs of research that might be supported by the Euratom research and training programme. Discussing this subject at the Observatory meetings, the stakeholders considered it vital to ensure availability of HEU during the transition period up to the (delayed) completion of the conversion process (2016/17), as the US, supplier of this material, has taken measures to minimise the use of HEU for civilian purposes (non-proliferation and nuclear security reasons). Until the conversion is fully in place, it will be necessary to guarantee the supply of HEU target material to ensure the uninterrupted production of medical radioisotopes. Another closely related aspect is the supply of uranium (both HEU and

([31]) OJ L 293, 5.11.2013, pp. 1-15.
([32]) The NEA established the HLG-MR in 2009 to examine the underlying reasons for the global 2009-10 supply shortage and to develop a policy approach to ensure the long-term security of supply of Mo-99/Tc-99m.
([33]) http://ec.europa.eu/euratom/docs/WG3 %20report.pdf
([34]) http://www.ema.europa.eu/ema
([35]) http://ec.europa.eu/health/files/eudralex/vol-1/reg_2012_712/reg_2012_712_en.pdf
([36]) http://www.hma.eu/cmdh.html

LEU) for fabrication of fuel for the European research reactors where the medical radioisotopes are produced.

With these objectives in mind, ESA was extensively involved, in 2014, in assessing requirements for these fissile materials and exploring the possibility of ensuring their supply. This has been a topic of discussion with the US and various EU countries during experts' meetings on uranium supplies for research reactors and Mo-99 production, organised by ESA and held in Luxembourg in 2014. In this context, ESA and the US Department of Energy — National Nuclear Security Administration signed, in December 2014, an MoU concerning the exchange of HEU needed for supply of European research reactors and radioisotope production facilities.

The conversion of irradiation targets from HEU to LEU and the increasing use of LEU as reactor fuel results in a higher demand for LEU. The supply of this material should also be ensured. As there is currently no production of such LEU (19.75 %) in the EU, the ESA Advisory Committee set up, in May 2012, a WG to study the feasibility of building European capacity designed to produce LEU metal. The study conducted by the WG leads to the conclusion that the building of a European enrichment facility is technically and legally feasible as well as being, under certain conditions, economically sustainable.

Nevertheless, as this constitutes very long-term planning, ESA, supported by its Advisory Committee, has suggested as a short-term alternative the signing of a framework agreement with the US to ensure medium-term supply of LEU. In this agreement, all necessary conditions would be set for single users to purchase the necessary material with a simplified contract and licensing requirements. In 2014, the conditions for signing such a framework contract and its concept were discussed between ESA and relevant US authorities.

As far as Euratom research requested in the Council conclusions is concerned, following the feedback received at the Observatory meetings, the European Commission included, in 2014, in the Euratom research and training programme, a topic on high-density LEU uranium fuel for research reactors and targets for the production of medical radioisotopes ([37]).

### *Working Group 4 — Capacity and infrastructure development*

The main objective of Working Group 4 (WG4) was to examine Mo-99 production capacity and infrastructure developments for both reactors and processing facilities. WG4 reviewed the current and future supply and demand data compiled by the OECD/NEA, using independent marketing and industry data as the basis for the report endorsed by the Observatory in July 2014. In this report the WG also took stock of the infrastructure and of the challenges that lie ahead to meet the demand for Mo-99 in the future ([38]).

According to the report, the data available show that for Europe the current demand is about 25 % of the global demand. The future trend is estimated at somewhere between 0 % growth and a line that reflects growth of 1.8 % per year between 2014 and 2020, and of 0.4 % from 2020 to 2030.

In the current situation, the demand is met by the established infrastructure, especially after several measures were put in place by the different players to mitigate the risk of shortages. These measures include effective coordination of the operating schedule of the reactors, the development of reserve capacity and arrangements whereby some processors are supplied by several irradiators, the upgrade of some processor facilities to operate round the clock, the full 52 weeks of the year, and more efficient use of Tc-99m by the healthcare end-users.

There are currently eight reactors producing the majority of the global supply of Mo-99. There are other local indigenous producers operating on a small scale (around 5 % of the total global volume). These eight reactors routinely supply irradiated targets to five Mo-99 processing facilities that distribute it to the Mo-99/Tc-99m generator manufacturers in Europe, the United States, Asia, South Africa, South America, and Australia.

However, the current supply chain for Mo-99 is fragile, as the shutdown of one or more of the major irradiators or processors might cause a shortage that the current infrastructure capacity might not be able to cover. This situation could become worse in the short term, given that three important irradiators are scheduled to be definitely or temporarily shut down this year (the licence of the Osiris reactor in France expires at the end of 2015, the BR-2 reactor in Belgium is undergoing a major 16-month refurbishing programme started in March 2015, and the NRU reactor in Canada will cease routine Mo-99 production in October 2016). In the longer term, the HFR reactor in the Netherlands is planned to be shut down in 2024, the BR-2 in 2026, the LVR-15 in the Czech Republic in 2028, and MARIA in Poland in 2030.

Thus, provision needs to be made for new capacity to replace the current production and to fill the gap in the market when the corresponding reactors are shut down. Such replacements can be made through Mo-99 produced by fission in new or existing research reactors (which can be adapted), or by other alternative reactor non-fission or accelerator-based methods, currently under development.

In Europe, four new projects are scheduled and could replace the Mo-99 production of the Osiris, HFR, and BR-2 reactors: FRM-II (Germany) with a new production capacity, 2017, and three new reactor builds: JHR (France), 2019 ([39]); Myrrha (Belgium), 2023; and Pallas (the Netherlands), 2024. These last two reactors are still in the design phase.

In the conclusion of the WG4 report it is stated that the existing network of reactors is fundamental to ensure the supply of medical radioisotopes to the market in the foreseeable future. The current capacity should be maintained by encouraging the necessary investments both to refurbish the current fleet, if appropriate, and to replace the capacity that will be lost as the operating reactors reach the end of their lifespan.

([37]) http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/2311-nfrp-08-2015.html
([38]) http://ec.europa.eu/euratom/docs/WG4_Report.pdf
([39]) JHR start-up is planned for 2019, but the first full year of Mo-99 production is expected in 2021.

# 6. The ESA work programme for 2014

In line with the Agency's remit under Chapter 6 of the Euratom Treaty and its statutes, the work programme of ESA for 2015 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**

The limited production of nuclear materials within the EU creates a need to diversify sources of supply to a satisfactory degree in order to guarantee the security of nuclear fuel supply to EU utilities. By evaluating and signing supply contracts for nuclear materials and acknowledging transactions covering provision of the entire cycle of nuclear fuel services, ESA will continue to guarantee security of supply, taking also fully into account the Commission communication of 28 May 2014 on the European Energy Security Strategy ([40]). The Agency will maintain a focus on the supplies of HEU and, increasingly, on the future supplies of LEU required for producing medical radioisotopes and fuelling research reactors.

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

ESA will continue to seek advice from its Advisory Committee on further development of the nuclear Observatory, including assessments of information tools created by the Agency. In this regard, ESA will continue to support the activities of the Advisory Committee's working groups.

3. **Increasing cooperation with international organisations and third countries**

In order to efficiently carry out the nuclear Observatory's tasks and to contribute to security of supply, ESA will actively pursue its relations with international bodies. Following up the MoU with the US DoE/NNSA, signed in December 2014, the Agency will take care of its implementation, coordinating, to the extent necessary, with the Member States concerned.

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

ESA will continue to follow developments in nuclear technology in order to anticipate possible changes in demand for nuclear fuel.

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

In order to streamline the contract-handling process and the market Observatory task, ESA will continue to update its internal manuals of procedures. Furthermore, it will review and revise its rules determining the manner in which demand is to be balanced against the supply of ores, source materials and special fissile materials.

## *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, paying particular attention to the diversification of sources of supply, which is an enhanced key priority of EU energy policy.

ESA monitors the diversification of sources by evaluating and signing the supply contracts for ores, source materials and special fissile materials produced within or outside the EU (Article 52 of the Euratom Treaty). Notifications to ESA of contracts for processing, converting or shaping materials (Article

([40]) COM(2014) 330, final.

75 of the Treaty) and of transactions involving small quantities (Article 74) also give the Agency an overview of needs and industrial capacity in the Union.

Exemption from the principle of diversification for contracts concluded before the EU accession of certain Member States will apply until the contracts expire ([41]) or are modified. New supply contracts for these utilities are being assessed in the light of the diversification policy.

ESA will continue to scrutinise potential risks to the security of supply of the HEU and LEU which are required to produce medical radioisotopes (Mo-99/Tc-99m) and fuel research reactors. Neither HEU nor such LEU is currently produced in the EU. ESA will be further actively involved in monitoring requirements for these fissile materials and striving to ensure their supply. 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 succeed in obtaining the necessary supplies in order to prevent any shortage in the production of medical radioisotopes.

**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 conformity with the EU supply/diversification policy and within the statutory deadline of 10 working days.

2. Acknowledge notifications of nuclear fuel transformation services, pursuant to Article 75 of the Euratom Treaty, in conformity with the EU supply/diversification policy and within the statutory deadline of 14 calendar days.

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

4. Keep on monitoring the 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, including through negotiations with supplier countries.

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

6. Verify, on request, the conformity of draft bilateral agreements between the EU Member States and non-EU countries with Chapter 6 of the Euratom Treaty.

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

([41]) Article 105 of the Euratom Treaty protects the rights acquired under these contracts until they expire.

## *Observing developments in the nuclear fuel market in the context of security of supply*

As the secretariat to the Advisory Committee's WG on security of supply scenarios, ESA will continue to facilitate the group's activities to increase the transparency of the nuclear fuel cycle market in the EU. Likewise, the Agency will provide support to the newly established WG on intermediaries.

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

These measures lay the foundation for building up comprehensive overviews of the situation and trends on 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.

ESA's nuclear market Observatory will continue to cooperate closely with the energy Observatory of the European Commission's Directorate-General for Energy.

Following the 2013 widening of ESA's Observatory role to cover aspects of the supply of medical radioisotopes in the EU, ESA will continue both to chair the European Observatory on the supply of medical radioisotopes set up in 2012 and to coordinate the European Commission services' actions undertaken to improve the security of supply of Mo-99/Tc-99m — the most vital medical radioisotope. ESA plans to issue, in 2015, a report to the European Commission, the Council and the European Parliament on activities following up the Council conclusions of 15 December 2009 on the security of supply of radioisotopes for medical use, as well as the Council conclusions of 6 December 2010 and 18 December 2012, 'Towards the secure supply of radioisotopes for medical use in the European Union'.

**Specific objective No 2**

To deliver on its market observation and monitoring responsibilities, ESA will:

1. continue to support the activities of the ESA Advisory Committee's WG on security of supply scenarios, and contribute to redefining the WG's remit;

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 June 2015;

4. continue to publish yearly natural uranium price indices: long-term, medium-term, 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. report to the Council on the follow-up to the Council conclusions on medical radioisotopes (present its report on the matter to the European Commission, the Council and the European Parliament);

8. provide support to the activities of the ESA Advisory Committee's WG on intermediaries.

## *Increasing cooperation with international organisations and third countries*

The quality and neutrality of ESA's analyses of the nuclear fuel cycle market are increasingly sought by groups of international experts. In order to raise the profile of its activities as a market Observatory and to carry out its other tasks efficiently, ESA will keep in 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 WNA and the World Nuclear Fuel Market (WNFM).

With a view to ensuring regular HEU supplies for as long as is necessary, ESA will continue its cooperation with the US DoE/NNSA, which was formally established through the MoU of December 2014.

**Specific objective No 3**

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

2. Participate in the negotiation of Euratom cooperation agreements with third 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 energy matters.

4. Maintain contacts with the US in view of the envisaged supply of HEU and LEU required for the production of medical radioisotopes.

## *Monitoring relevant research and development activities and evaluating their impact on ESA's security of supply policy*

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

**Specific objective No 4**

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

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

## *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 ESA's budgetary autonomy in the general budget of the EU.

**Specific objective No 5**

1. Review the current ESA practices and work arrangements as well as ESA's internal control standards; continue to update the manual of procedures for the contracts and market Observatory sectors.

2. Ensure sound financial and budgetary management.

3. Review/update the MoU with the European Commission's Directorate-General for Energy.

4. Review and revise the Agency's rules determining the manner in which demand is to be balanced against the supply of ores, source materials and special fissile materials (pursuant to Article 60(6) of the Euratom Treaty and Article 13(3), of the Agency's statutes).

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This report and previous editions are available on ESA's website (http://ec.europa.eu/euratom/index_en.html).

A limited number of paper copies of this report may be obtained, subject to availability, on simple request to ESA.

## Further information

Additional information can be found on Europa, the European Union server (http://europa.eu/index_en.htm).

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

The Internet address of the European Commission's Directorate-General for Energy is: 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.

# Glossary

**Generation IV** (or Gen-IV) reactors are a set of nuclear reactor designs currently being developed through research cooperation within the Generation IV International Forum. Current reactors in operation around the world are generally considered second- or third-generation systems. The primary goals of Gen-IV are to improve nuclear safety, improve resistance to proliferation, minimise waste and consumption of natural resources and reduce the cost of building and running such plants. These systems employ a closed fuel cycle to maximise the resource base and minimise the high-level waste to be sent to a repository. Most of them are fast-neutron reactors (only two operate with slow neutrons, like today's plants). They are not expected to be available for commercial construction before 2030.

High-enriched uranium (**HEU**) is uranium enriched to 20 % U-235 or more (usually up to 93 %).

Low-enriched uranium (**LEU**) is uranium enriched to less than 20 % U-235. For power reactors, it is usually 3.5-5.0 % U-235.

**MW** stands for megawatt or 1 million watts and is a measure of electrical output. MWe refers to electrical output from a generator, MWt to thermal output from a reactor or heat source (e.g. the gross heat output of a reactor itself, typically around three times the MWe figure).

**SWU** stands for 'separative work unit'. SWUs measure the effort made in order to separate the fissile, and hence valuable, U-235 isotopes from the non-fissile U-238 isotopes, both of which are present in natural uranium. As a standard indicator of enrichment services, the concept of SWU is very complex, as it is a function of the amount of uranium processed and the degree to which it is enriched (i.e. the extent of increase in the concentration of the U-235 isotope relative to the remainder). The unit — strictly 'kilogram separative work unit' or kg SWU, when feed and product quantities are expressed in kilograms (but usually shown in graphs as SWUs, or tSW for 1 000 SWUs) — is a measure of the quantity of separative work (indicative of energy used in enrichment).

**Radioisotopes** are used in medicine for the diagnosis and treatment of various diseases, including some of the most important ones, like cancers, or cardiovascular and brain diseases. Over 10 000 hospitals worldwide use radioisotopes for the *in vivo* diagnosis or treatment of about 35 million patients every year, including 9 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-99m (Tc-99m) is the most widely used (diagnostic) radioisotope. Europe is the second largest consumer of Tc-99m, accounting for more than 20 % of the global market. The production of Tc-99m 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-99m generators and shipment to hospitals. Due to their short decay times, Mo-99 and Tc-99m 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. Unfortunately, the current Mo-99/Tc-99m supply relies on a small number of production reactors. Moreover, as those reactors were constructed in the 1950s and 1960s, they are approaching the end of their lifespan, which creates an increasing need for planned maintenance shutdowns and a growing frequency of unplanned production interruptions. As a result, the global supply of radioisotopes has become more fragile, particularly in recent years.

# Annexes

## Annex 1
## EU-28 gross and net requirements (quantities in tU and tSW)

### (A) From 2015 until 2024

| Year | Natural uranium | | Separative work | |
|---|---|---|---|---|
| | Gross requirements | Net requirements | Gross requirements | Net requirements |
| 2015 | 18 248 | 15 191 | 14 468 | 12 167 |
| 2016 | 17 906 | 15 678 | 14 426 | 12 763 |
| 2017 | 19 321 | 16 294 | 15 597 | 13 375 |
| 2018 | 17 180 | 15 064 | 14 524 | 13 083 |
| 2019 | 17 776 | 16 475 | 14 375 | 13 379 |
| 2020 | 17 115 | 15 489 | 13 746 | 12 890 |
| 2021 | 18 069 | 16 626 | 13 718 | 12 921 |
| 2022 | 17 352 | 15 910 | 13 896 | 13 098 |
| 2023 | 17 162 | 15 719 | 14 035 | 13 238 |
| 2024 | 16 218 | 14 775 | 13 229 | 12 432 |
| **Total** | **176 346** | **157 221** | **142 013** | **129 346** |
| **Average** | **17 635** | **15 722** | **14 201** | **12 935** |

### (B) Extended forecast from 2025 to 2034

| Year | Natural uranium | | Separative work | |
|---|---|---|---|---|
| | Gross requirements | Net requirements | Gross requirements | Net requirements |
| 2025 | 15 225 | 13 779 | 12 436 | 11 637 |
| 2026 | 15 302 | 13 788 | 12 505 | 11 658 |
| 2027 | 14 985 | 13 575 | 12 271 | 11 501 |
| 2028 | 14 908 | 13 294 | 12 197 | 11 265 |
| 2029 | 14 858 | 13 355 | 12 186 | 11 348 |
| 2030 | 14 666 | 13 256 | 12 045 | 11 275 |
| 2031 | 14 429 | 13 019 | 11 848 | 11 078 |
| 2032 | 14 766 | 13 279 | 12 118 | 11 284 |
| 2033 | 14 419 | 12 933 | 11 861 | 11 027 |
| 2034 | 14 231 | 12 821 | 11 692 | 10 922 |
| **Total** | **147 789** | **133 099** | **121 160** | **112 994** |
| **Average** | **14 779** | **13 310** | **12 116** | **11 299** |

## 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 | (1) | |
| 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** |

(1) Data not available.

## 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 | (1) 21.00 | (1) 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 | (2) 63.49 | (2) 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** |

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

(2) 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, 2006-14 (tU)

| Country/region | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|---|---|---|
| **Kazakhstan** | 527 | 557 | 1 072 | 1 596 | 2 816 | 2 659 | 2 254 | 3 612 | 3 941 |
| **Russia** | 3 984 | 5 144 | 3 272 | 3 599 | 4 979 | 4 524 | 5 102 | 3 084 | 2 649 |
| **Niger** | 3 355 | 3 531 | 1 845 | 1 854 | 2 082 | 1 726 | 2 376 | 2 235 | 2 171 |
| **Australia** | 3 053 | 3 209 | 2 992 | 3 801 | 2 153 | 1 777 | 2 280 | 2 011 | 1 994 |
| **Canada** | 5 093 | 3 786 | 4 757 | 3 286 | 2 012 | 3 318 | 3 212 | 3 156 | 1 855 |
| **US** | 488 | 402 | 398 | 318 | 320 | 180 | 241 | 381 | 586 |
| **EU** | 472 | 526 | 515 | 480 | 556 | 455 | 421 | 421 | 397 |
| **Uzbekistan** | 530 | 938 | 1 070 | 589 | 459 | 929 | 159 | 653 | 365 |
| **Namibia** | 790 | 865 | 696 | 435 | 1 017 | 1 011 | 1 350 | 716 | 325 |
| **Other** | 1 336 | 432 | 520 | 329 | 432 | 128 | 256 | 621 | 299 |
| **Malawi** | 0 | 0 | 0 | 0 | 0 | 0 | 180 | 115 | 125 |
| **Ukraine** | 0 | 123 | 0 | 10 | 0 | 284 | 0 | 0 | 23 |
| **South Africa** | 188 | 137 | 247 | 426 | 190 | 113 | 412 | 17 | 20 |
| **HEU feed** | 850 | 825 | 550 | 675 | 550 | 731 | 395 | 0 | 0 |
| **Re-enriched tails** | 728 | 388 | 688 | 193 | 0 | 0 | 0 | 0 | 0 |
| Total | **21 394** | **20 864** | **18 622** | **17 591** | **17 566** | **17 832** | **18 639** | **17 023** | **14 751** |

## 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 |
| **Grand total** | **184 239** | **20 956** | **14 096** |

## Annex 6
## EU nuclear utilities contributing to this report

| |
|---|
| ČEZ, a.s. |
| EDF and EDF Energy |
| EnBW Kernkraft GmbH |
| ENUSA Industrias Avanzadas, S.A. |
| E.ON Kernkraft GmbH |
| EPZ |
| Fortum Power |
| Ignalina NPP |
| Kozloduy NPP Plc |
| Magnox Ltd (UAM) |
| Nuklearna elektrarna Krško, d.o.o. |
| Oskarshamn NPP (OKG) |
| Paks NPP Ltd |
| 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 (formerly Cogéma) |
| AREVA Mines |
| Aron |
| BHP Billiton (formerly WMC) |
| Cameco Inc. Corporation USA |
| CNU |
| Cominak |
| DIAMO |
| Energy US |
| Internexco GmbH |
| Itochuint |
| KazAtomProm |
| Macquarie Bank Limited, London Branch |
| 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 three years (i.e. between 1 January 2012 and 31 December 2014) 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 provided 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:

• 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 reliably to 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.

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