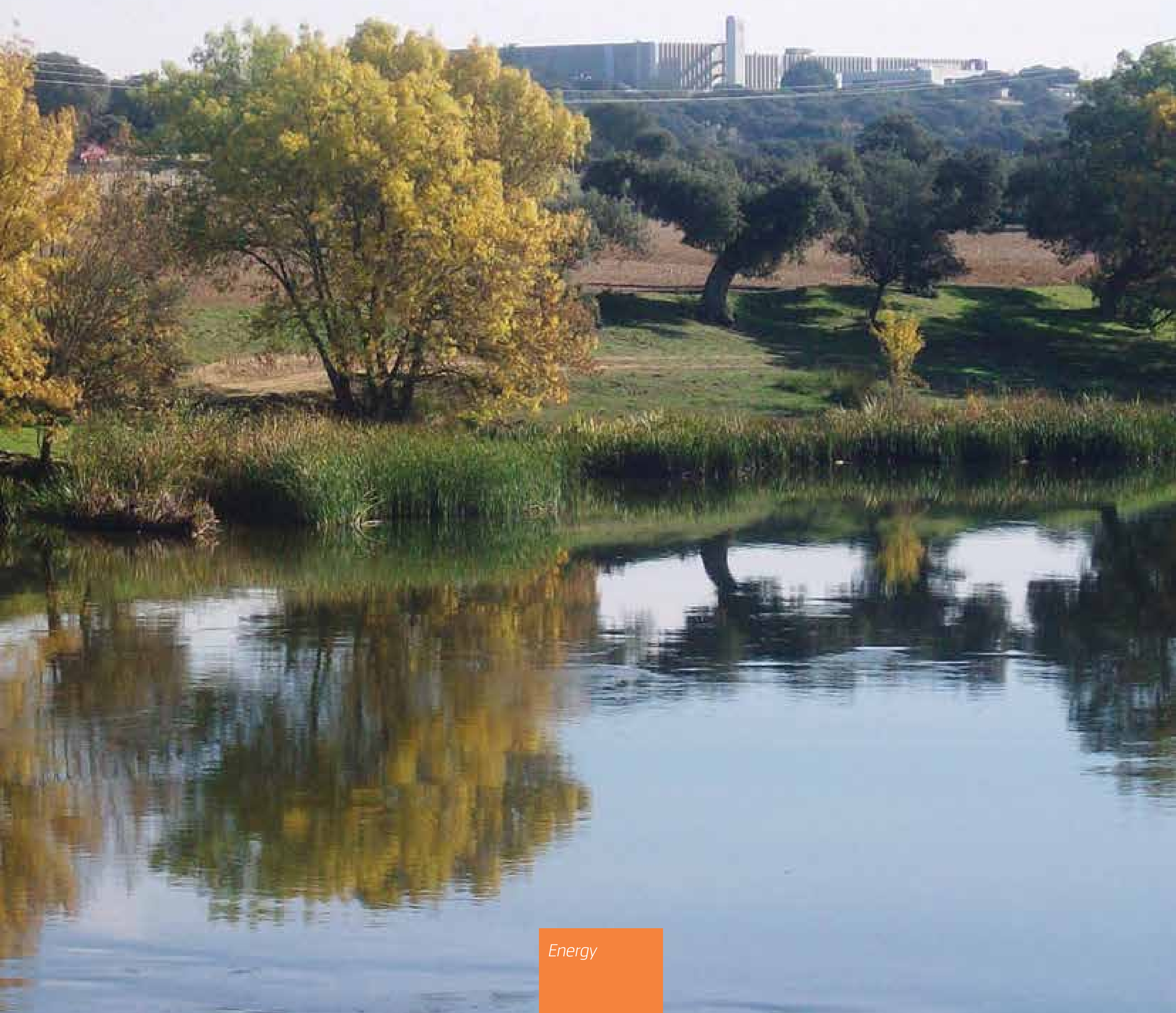
European Commission

ISSN 1683-3481

# EURATOM
# Supply Agency

## ANNUAL REPORT **2015**



*Energy*

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

Cover photo: Exteriores fábrica de elementos combustibles Juzbado © ENUSA

Luxembourg: Publications Office of the European Union, 2016

| | | | | |
|---|---|---|---|---|
| Print | ISBN 978-92-79-58374-2 | ISSN 0257-9138 | doi:10.2833/798462 | MJ-AA-16-001-EN-C |
| PDF | ISBN 978-92-79-58373-5 | ISSN 1683-3481 | doi:10.2833/36688 | MJ-AA-16-001-EN-N |
| EPUB | ISBN 978-92-79-58375-9 | ISSN 1683-3481 | doi:10.2833/0467 | MJ-AA-16-001-EN-E |


*Printed in Belgium*

PRINTED ON ELEMENTAL CHLORINE-FREE BLEACHED PAPER (ECF)

# Contents

# Abbreviations

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

The 2015 Annual Report of the Euratom Supply Agency (ESA) maintains the structure of the previous one, including separate chapters on the security of supply and on medical radio-isotopes.

Aside from carrying out its contractual and monitoring activities, in 2015 ESA focused on updating its Rules for balancing demand and supply, as the ones in force date back to 1960 and were only partially revised in 1975. The goal is to come up with a set of provisions that are better adapted to today's nuclear fuel market. I hope that this project will be finalised within the current year, to provide ESA and its stakeholders with an up-to-date foundation for their work.

I would like to highlight and praise the work of the Working Groups (WG) of ESA's Advisory Committee. Thanks to its members' expertise and strong continuous commitment, the WG on Prices and Security of Supply provided substantial assistance to ESA's Nuclear Market Observatory, enabling it to further increase transparency in the market concerned. The WG on Intermediaries offered useful insight into the role and operation of intermediary companies in the uranium market, which has been helpful to the work on updating ESA's Rules.

Follow-up work to the Memorandum of Understanding between ESA and the DoE/NNSA of the United States on the exchange of high-enriched uranium (HEU) was also one of the 2015 highlights. The Memorandum aims to ensure the supply of HEU for European Research Reactors and producers of radioisotopes in conformity with the policy of reduction of HEU in civil uses, developed in the process of the Nuclear Security Summits.

In the previous report, I was in a position to stress the quality of our work, based, inter alia, on the stability of our team. This team will change in 2016, as both the Head of Unit for Nuclear Fuel Market Operations and myself, as ESA's Director-General, are due to retire in the course of this year.

I trust that the expected changes in Management will not adversely affect the Agency's performance, as our successors will find, when they come into office, a competent and motivated team, eager to help them maintain and improve ESA's work.

As this is the last Annual Report for which I am responsible, I would like to close this foreword by conveying my best wishes to the Euratom Supply Agency and its stakeholders for a successful future.

Stamatios Tsalas

Director-General of the Euratom Supply Agency

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

## EU nuclear energy policy in 2015

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.

### *Strategic agenda for nuclear energy*

As part of the implementation of the Energy Union Strategy ([1]), the Directorate-General for Energy prepared a draft Nuclear Illustrative Programme to provide a full overview of developments and investments needed in the nuclear field in the EU for all the steps of the nuclear lifecycle with a 2050 horizon. The proposed initiative includes investments related to post-Fukushima safety upgrades and to the safe long-term operation of existing facilities, thereby reflecting the key importance of nuclear safety for European Commission actions. It covers the financing needs related both to new nuclear power plants and to nuclear power plants' decommissioning as well as the management of radioactive waste and spent fuel, including the financing of long-term solutions such as the construction of deep geological disposal facilities. Finally, it also addresses the need for investments in research reactors and the associated fuel cycle, including the production of medical radioisotopes. Final adoption is expected later in 2016, after consultation with the European Economic and Social Committee.

In its Energy Union Strategy, the Commission stated its intention to update and strengthen the requirements to provide information on nuclear investments in accordance with Article 41 of the Euratom Treaty. This is to simplify existing requirements and shorten the time scale of delivering a Commission opinion on investments, and to ensure that security of supply is properly taken into account in the assessment of investment projects. The Commission's proposal should be adopted in June 2016.

([1]) https://ec.europa.eu/priorities/energy-union-and-climate_en

In 2015, the European Commission also started preparing a recommendation on the application of Article 103 of the Euratom Treaty, planned to be adopted together with the Nuclear Illustrative Programme. The main objective of the initiative is to ensure that security supply aspects are duly taken into account when Member States enter into agreements with third countries.

### *Nuclear safety directive*

As regards the amended Nuclear Safety Directive ([2]), the Commission organised a first workshop with Member States in October 2015, with a view to facilitating the directive's timely and effective transposition by August 2017. The Commission will continue to support Member States in transposing the amendment into national law by organising workshops/seminars and through the work of the European Nuclear Safety Regulators Group (Ensreg). The Commission's report on the implementation of the 2009 nuclear safety directive has been adopted by the College on 18 November 2015 and is annexed to the State of Energy Union Report ([3]).

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

Ensreg ([4]) met three times in 2015. Ensreg decided to redraft its work programme in 2016 to refocus and realign its activities with the Commission's priority objectives in support of the implementation of the nuclear safety directive, Waste and Spent Fuel Directive and the Basic Safety Standards Directive. Furthermore, it agreed on *Aging Management* as the topic for the 2017 topical peer review exercise under the amended nuclear safety directive.

([2]) OJ L 219, 25.7.2014, pp. 42-52.
([3]) https://ec.europa.eu/priorities/energy-union-and-climate/state-energy-union_en
([4]) http://www.ensreg.eu/

Ensreg held its third conference in Brussels on 29-30 June 2015. The event brought together around 300 delegates including national regulators, NGOs, nuclear operators and academics. It focused on the continuous improvement of nuclear safety and the challenges facing nuclear energy throughout the nuclear fuel cycle.

### *Stress tests*

As a follow up to the nuclear stress tests, national action plans were prepared by all participating countries. They were revised in late 2014 and were reviewed by national regulators and Commission staff during a workshop held in the spring of 2015. This workshop focused in particular on evaluating progress made in the implementation process, including additional measures undertaken and changes to the original schedule.

As for neighbouring countries, Armenia delivered its stress test report in August 2015, and this will be peer reviewed in 2016 with Commission support. Regular contacts are also maintained with Belarus, who started preparing its stress test report in 2015.

### *European Nuclear Energy Forum (ENEF)*

The 2015 ENEF plenary meeting was held in Prague in May (5). It focused on the role of nuclear energy in the Energy Union, on security of supply, on the importance of ensuring that the highest standards for nuclear safety are implemented and continuously improved in the EU, and on perspectives for the nuclear decommissioning market. The conclusions highlighted the crucial involvement of civil society, noting that all actors have to strengthen their efforts to provide transparent and comprehensive information about future developments and to engage actively in a dialogue with civil society where appropriate.

### *Convention on Nuclear Safety*

In the framework of the Convention on Nuclear Safety (CNS) Diplomatic Conference, held in February 2015 in Vienna, a set of principles and implementation mechanisms to improve the safety of nuclear power plants were approved by consensus of all attending contracting parties, including the 28 Member States and the Euratom Community. The contracting parties committed to the immediate implementation of the so-called Vienna Declaration, which will be subject to peer reviews starting in 2017 in the framework of the next CNS Review Meeting. This outcome is largely in line with the Commission's goal to promote the 'safety objective', as introduced by the amended Nuclear Safety Directive, beyond the EU's borders.

### *Safe management of radioactive waste and spent fuel*

Following the adoption of the Council Directive establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste in 2011 (6), efforts were focused on assessing the transposition measures notified by Member States. By the end of 2015, 27 Member States had reported full transposition and one Member State had reported partial transposition. A review of the completeness and conformity of the notified transposition measures was carried out to make sure that the relevant provisions in the Member States comply with the directive's requirements and aim to ensure the responsible and safe management of spent fuel and radioactive waste.

### *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management*

The Commission delivered the Euratom report at the 5th Review Meeting of the Joint Convention on spent fuel and radioactive waste (7), which took place at the International Atomic Energy Agency (IAEA) in May 2015. Euratom also organised a side event on the waste directive, attended by about 80 participants. A joint Euratom/US proposal on possible activities to increase Joint Convention membership was well received by the contracting parties. It is being implemented by the IAEA secretariat and the Joint Convention leadership.

### *Notifications received under the Euratom Treaty provisions*

The Commission delivered nine opinions in 2015, on general data submitted by Member States on plans for the disposal of radioactive waste under Article 37 of the Euratom Treaty:

- two on new plans (the European Spallation Source Facility at Lund in Sweden and the Liquid Sludge Treatment Plant at Sellafield in the United Kingdom);
- two on the modification of existing plans (the Dounreay Site Restoration in Scotland and the CIRES repository for very low active waste in France);
- five on dismantling plans, as follows: (i) the KKI-1 BWR at Isar in Germany (ii) the Phénix FBR at Marcoule in France (iii) the dismantling stages III + IV of the Bohunice A-1 reactor in Slovakia (iv) the 2 PWR of KWB at Biblis in Germany and (v) the UP2-400 spent fuel reprocessing plant at La Hague in France.

(5) https://ec.europa.eu/energy/en/events/2015-european-nuclear-energy-forum-enef-plenary-meeting

(6) OJ L 199, 2.8.2011, pp. 48-56.

(7) http://www-ns.iaea.org/conventions/waste-jointconvention.asp

The Commission adopted six opinions under the procedure to notify investments in the nuclear domain (Article 41 of the Euratom Treaty) in 2015. Two of them dealt with planned investments in the construction of nuclear power reactors: the first assessed the building of two Russian-type nuclear power reactors at PAKS in Hungary, while the second reviewed the plan of a Finnish investor to build a nuclear reactor at Hanhikivi. One opinion was adopted on a first-of-a-kind project dealing with an encapsulation plant along with an underground repository site for spent nuclear fuel in Finland and two others were adopted on projects dealing with mining and uranium facilities in Spain. Finally, the Commission adopted an opinion on the replacement of important components in a nuclear power plant in Finland.

## *EU support for nuclear decommissioning assistance programmes*

As provided for in Article 6 of Council Regulations (Euratom) 1368/2013 ([8]) and (EU) 1369/2013 ([9]) defining the Bohunice, Kozloduy and Ignalina decommissioning programmes for 2014-2020, the European Commission adopted the 2015 annual work programmes and the associated financing decisions, allocating EUR 132.984 million for the implementation of the actions. These adopted annual work programmes set out the activities for the year 2015 and update the schedule for the completion of the programme.

The 2015 funds earmarked for Lithuania and Bulgaria were committed in October and December 2015, respectively; for Slovakia, the 2015 commitment is pending conclusion of the delegation agreement with the Slovak Innovation and Energy Agency.

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

The Commission has continued to work on revising the Euratom-Canada nuclear cooperation agreement and on obtaining the Council's approval for opening negotiations with the Republic of Korea on an agreement for cooperation on the peaceful uses of nuclear energy. During discussions in the Council and with stakeholders, the issue of technology transfer was raised and will be followed up in 2016. The Commission also started preparatory work in view of possible future Euratom agreements with the United Arab Emirates and China.

## *Convention on the Physical Protection of Nuclear Material*

In 2005, a diplomatic conference was held with the aim of strengthening the Convention on the Physical Protection of Nuclear Material ([10]) as well as expanding its scope. Following the ratification of the amended Convention on the Physical Protection of Nuclear Material and Nuclear Facilities by the last EU Member States, the Euratom Community was able to deposit its own instrument of ratification in December 2015. Now that all Member States and Euratom have ratified the amended Convention, a further twelve States Parties must ratify it in order for the Convention to enter into force. The completion of the ratification process by all Member States and the Euratom Community was an important political signal in view of the 2016 Nuclear Security Summit.

## *Basic safety standards*

The Commission continued its comprehensive strategy for monitoring and supporting the transposition of the revised Basic Safety Standards (BSS) Directive ([11]). It organised workshops with EU Member States on their implementation of the directive as well as a workshop on the BSS emergency preparedness and response arrangements with the participation of civil society. It is envisaged that four additional workshops on selected areas of the BSS Directive will be organised with Member States in 2016, with a fifth one planned for early 2017. The Commission will continue to place particular emphasis on civil society's views and expectations related to the issue of emergency preparedness and response.

## *Euratom drinking water directive*

Member States were required to transpose Council Directive 2013/51/Euratom (the 'Euratom Drinking Water Directive') ([12]) by 28 November 2015. 16 Member States notified the Commission of their transposing legislation in 2015.

## *Radioactive contamination of food and feed*

The European Commission adopted its final proposal for a Council Regulation laying down maximum permitted levels of radioactive contamination of food and feed ([13]) following a nuclear accident or any other case of radiological emergency (Revision of Council Regulation 3954/87/Euratom). After receiving the opinion of the European Parliament in July 2015, the Regulation was adopted on 15 January 2016.

## *International Thermonuclear Experimental Reactor (ITER)*

The ITER ([14]) project and all ITER units were transferred to the Directorate-General for Energy as of 1 July 2015. Since the

([8]) OJ L 346, 20.12.2013, pp. 1-6.
([9]) OJ L 346, 20.12.2013, pp. 7-11.
([10]) http://www-ns.iaea.org/conventions/physical-protection.asp?s=6&l=42
([11]) OJ L 13, 17.1.2014, pp.1-69.
([12]) OJ L 296, 7.11.2013, pp. 12-21.
([13]) COM(2013) 943.
([14]) https://www.iter.org/

transfer of responsibilities, the Directorate-General for Energy has taken action to define, clarify and structure the Commission's response to the challenges of the ITER project. The underlying rationale of these actions was to prepare a solid and stable ground for the Commission to decide on the next steps for ITER. A fully-fledged strategic approach to the management of ITER and Fusion for Energy (F4E) is being rolled out, including on governance issues, relations with the institutions, and working methods within the Commission.

## Main developments in the EU Member States

In early 2015, the Commission released a series of proposals that call for developing an Energy Union through increased harmonisation of the 28 energy markets, which should become increasingly diversified and energy-efficient. The newly formed European Energy Union allows each Member State to decide whether nuclear energy should be part of its energy mix, but sees it as a key power source for meeting the EU's clean energy targets, such as security of supply through diversification of nuclear fuel supplies, decarbonisation of the electricity sector, and competitive power prices.

As explained further on in this document, several Member States share the view that nuclear energy can contribute to cleaner electricity. However, major investments are required in nuclear new build , lifetime extension and safety upgrades, improved fuel cycle operation, decommissioning and waste management.

Some national energy policies provide for a higher share of nuclear in the national energy generation mix, alongside renewables. Nuclear plant construction continued in France, Slovakia and Finland, although it was affected by various regulatory and financial obstacles. Moderate progress was reported on new build projects and intentions in Bulgaria, the Czech Republic, Lithuania, Hungary, Poland, Romania, Finland and the United Kingdom. Governmental approval has been granted for operational lifetime extension of certain nuclear power plants (NPPs) (Belgium, Bulgaria, France, Slovenia and the United Kingdom) and power uprates (Sweden). Prolonged fuel cycles have been achieved through use of improved fuel in Hungary and Slovakia. Several countries have launched projects on waste management. Apart from the early closure of two reactors (Germany and Sweden), one reactor in the United Kingdom was also shut down as had been long anticipated. As an increasingly visible player on the nuclear market, China was also chosen as partner for various bilateral agreements or Memoranda of Understanding providing either for cooperation on research in the field of civil nuclear power or for potential new builds (Romania, Slovakia and the United Kingdom).

### Table 1. Nuclear power reactors in the EU in 2015

| Country | Reactors in operation (under construction) | Net capacity (MWe) |
|---|---|---|
| Belgium | 7 | 5 943 |
| Bulgaria | 2 | 1 926 |
| Czech Republic | 6 | 3 940 |
| Germany | 8 | 10 728 |
| Spain | 7 | 7 002 |
| France | 58 (1) | 63 130 |
| Hungary | 4 | 1 889 |
| Netherlands | 1 | 485 |
| Romania | 2 | 1 310 |
| Slovenia/Croatia (*) | 1 | 696 |
| Slovakia | 4 (2) | 1 816 |
| Finland | 4 (1) | 2 741 |
| Sweden | 9 | 8 849 |
| United Kingdom | 15 | 8 883 |
| **Total** | **128 (4)** | **119 302** |

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

*Source:* World Nuclear Association (WNA).

As shown in Table 1, at the end of 2015 a total of 128 nuclear power reactors, of different designs, were in operation in the EU, producing 27.5 % of its electricity; four more were under construction. Three reactors were shut down in the EU in 2015: the single-unit Grafenrheinfeld NPP in Germany, Oskarshamm Unit 2 in Sweden, and Wylfa Unit 1, the oldest reactor in the United Kingdom.

**Country-specific developments in 2015**

**Belgium:** In September, the Belgian Constitutional Court rejected the appeal submitted by Electrabel and EDF-Luminus on the legality of the government doubling the nuclear tax in 2012. The tax was meant to allow the state to benefit from profits made by nuclear reactor operators originally built with state support, but was considered by Electrabel and EDF-Luminus as illegal state aid, not taking into account the decrease in profits from Belgian nuclear generation. According to the Court, the tax is legitimate and in the general interest. In July, the Belgian government announced that it had reached an agreement with Electrabel to amend future nuclear taxes as part of a broader agreement on nuclear generation in Belgium.

Units 1 and 2 at the Doel nuclear power plant will remain online for 10 more years, until 2025, following the agreement reached between Electrabel, the reactor's operator, and Belgium's government. According to Belgium's Ministry of Energy, the lifespan extensions were needed in order to maintain a reliable supply of electricity for Belgium, which currently depends on nuclear power for about 50 % of its electricity. The two units were reconnected to the grid in December 2015, together with Unit 3 at Doel and Unit 2 at Tihange NPP, following approval granted by Belgium's Federal Agency for Nuclear Control.

**Bulgaria:** Most of the preliminary activities linked to Kozloduy NPP-New Build Company's project, based on the newest generation III or III+ PWR technology, have been already completed. The project should be implemented with the involvement of a strategic investor, taking due account of the EU State aid rules. Negotiations on a new structure and schedule for the project have started.

In line with the country's energy strategy adopted in 2014, Kozloduy Nuclear Power Plant plc and a consortium of Russia's Rusatom Services and Bulgaria's Risk Engineering Ltd have signed an agreement to extend the operating life of Unit 6 of the Kozloduy NPP to 60 years, as already done in 2014 for Unit 5. The reactor's upgrade should be completed in 2018. Besides extending its lifespan, this will allow the reactor, currently licensed to operate until 2019, to operate at a higher power level.

**Czech Republic:** According to a long-term energy strategy published by the country's Ministry of Industry and Trade in May, nuclear power's share in the Czech Republic's electricity generation mix is expected to rise from about 35 % currently to between 46 % and 58 % by 2040. With regard to new build, the government will prioritise adding new unit(s) to the current Dukovany site, where the reactors in operation are older than the ones at the Temelin site, and where there has been strong local support for additional nuclear capacity.

As for the existing units at the Dukovany NPP, three out of four have been temporarily put out of operation since September because of flawed and insufficiently documented safety checks of welds of piping regarding the water tightness. The main security systems were not concerned. The units were restarted again at the end of 2015 / beginning of 2016.

**Germany**: In June, the European Court of Justice ruled that Germany's tax on nuclear fuel does not breach any EU laws.

E.ON and Vattenfall signed an agreement to cooperate on the decommissioning and dismantling of their jointly owned NPPs in Germany.

In the summer of 2015, Germany shut down its oldest operational reactor, Grafenrheinfeld, 6 months ahead of schedule. The closure of the 1 345 MW reactor is part of the country's nuclear phase-out strategy and leaves it with eight operating nuclear reactors. According to E.ON, the Grafenrheinfeld reactor's operator, the 33-year-old reactor was the world's first reactor to reach an annual output of 10 TWh, which it did in 1984; it generated a total of 333 TWh of electricity during its operating lifetime.

Based on a proposal put forward by the country's environment ministry and after conducting a strategic environmental assessment and a public consultation, the German cabinet adopted in August a draft national radioactive waste disposal programme. The results of a government-commissioned report have shown that the German nuclear energy suppliers have sufficient funds to cover the costs of decommissioning their NPPs and dispose of all radioactive waste.

**Spain**: In April, the Spanish nuclear plant operator Nuclenor confirmed to the country's regulator that the results of inspections carried out on the reactor vessel of Spain's shut down Garoña NPP showed that the reactor was in good condition to work safely when restarted.

In July, Spain's nuclear regulator concluded that Villar de Cañas is a suitable site to host a national high-level waste storage facility, while requesting, however, additional technical studies and reports.

In November, Berkeley Energy Ltd announced that, following siting authorisation from Spain's Ministry of Industry, Energy and Tourism, the company had received the EU-, national-, regional-, and provincial-level preliminary approval required for the initial development of infrastructure for the Salamanca uranium project. With the mining license and the environmental statement already obtained, the approvals still to come include the locally issued urbanism licence and the construction authorisation, which could be obtained ahead of the estimated start date of mid-2017. According to Berkeley, the Salamanca Pre-Feasibility Study shows construction works as beginning in 2016, with first production in 2017 and a mine life estimated at 18 years at a production rate of approximately 1 120 tU per year.

**France:** ASN, the country's nuclear regulator, accepted EDF's technical approval requirements for using its 1 300-MW power reactors for an additional 10 years, for a total operating lifespan of 40 years. Currently, EDF operates 20 reactors of this type at eight different sites in France. The decision follows EDF's commitments to further improve plant safety. An assessment carried out by the nuclear regulator showed no generic elements that would prevent the safe operation of these reactors over 40 years.

In July, France adopted the 'Energy Transition for Green Growth' act, which aims to reduce the country's reliance on nuclear power to 50 % of power generation by 2025. The bill includes a cap on French nuclear power production at its current 63.2 gigawatt level and requires that renewable energy sources increase to reach 40 % of electricity production by 2030. The EPR Flamanville unit is expected to have the first core loading at the end of 2018.

EDF and AREVA have signed a Memorandum of Understanding according to which EDF will take a stake of at least 51 % in AREVA NP, the company responsible for the design and construction of nuclear reactors, equipment and fuel manufacturing, as well as providing services for reactors. AREVA will hold a maximum stake of 25 %, allowing for other possible participation. Mitsubishi Heavy Industries (MHI) has already stated its intention to present a proposal for a minority share in AREVA's reactor business. The project aims to better secure the most critical activities of the lifetime extension programme for the existing fleet in France, in terms of improved efficiency of engineering services, project management, and some manufacturing. The agreement also paves the way for the establishment of a dedicated company, 80 % EDF- and 20 % AREVA-owned, responsible for the design, project management and marketing of new reactors. This company intends to harmonise and expand the range of reactors, while preparing more competitive reactor offers. The Memorandum of Understanding also sets the terms of cooperation between the two companies in areas such as research and development, international sales of new reactors, disposal of spent fuel, and decommissioning.

As regards the construction of the Jules Horowitz [research] reactor, 2015 was a major year for civil works, as well as for components manufacturing. Final qualification tests of the main control rod mechanisms were also performed.

As far as the CERCA (AREVA NP) facility is concerned, ESA, in its report to the Commission on the security of supply of medical radioisotopes, identified it as the sole European supplier of uranium targets used for medical radioisotope production and, therefore, as one of the essential links in the European supply chain.

CERCA is also the only European manufacturer of fuel for research reactors, some of which are involved in the production of medical radioisotopes. There are also new research reactors planned or under construction and they will need fuel supply over several decades. AREVA NP is investing in a state-of-the-art upgrade of the CERCA facility, in order to ensure a sustainable supply for its customers, many of them European, while satisfying the requirements of security and safety in compliance with current and future anticipated standards.

In October 2015, under Article 41 of the Euratom Treaty, the Commission was notified of an investment project in view of upgrading the CERCA facility.

**Hungary:** Following lengthy discussions, the Euratom Supply Agency concluded the amended supply contract between Hungary and Russia on nuclear fuel supply for the Paks II expansion project. However, the Commission has started investigations concerning possible state aid and the respect of EU public procurement rules in the Paks II project.

**Netherlands:** In May, the Belgian company Tractebel Engineering signed a contract to be the 'Owner's Engineer' for the planned Pallas research reactor at Petten. In December, the Dutch engineering company ARCADIS got the role of 'Licensing Engineer' and 'Off Plot Scope Designer' (LEOPS). When completed, the new facility is meant to replace the current HFR as a major worldwide supplier of medical radioisotopes.

**Lithuania**: In December, the country's nuclear regulator issued a licence for the construction and operation of a very low-level radioactive waste disposal facility near the Ignalina NPP.

According to Lithuania's Energy Minister and Hitachi, the strategic investor chosen for the construction of the Visaginas NPP, there has been very little progress regarding negotiations on the new nuclear reactor.

**Poland:** According to Poland's transmission system operator and largest power company, PSE, the country's nuclear programme has encountered further delays. Consequently, it is expected that the first unit will be completed in 2029, rather than 2024, as was indicated in an earlier government timetable.

In November, it was made public that five companies were interested in taking part in the tender for the construction of the country's first NPP, namely GE-Hitachi, Korea Electric Power Corp., SNC-Lavalin, Westinghouse and EDF/AREVA. The tender will include reactor technology, engineering, procurement and construction services, fuel supply, investment by a potential strategic partner, and debt financing.

**Romania:** In November, the Romanian utility Nuclearelectrica announced that it had signed a Memorandum of Understanding with China General Nuclear Power Corporation for the development, construction, and operation of Units 3 and 4 at the Cernavoda NPP, with a capacity of 700 MW each and based on the CANDU 6 reactor design. According to the 2014 strategy approved by the Romanian government, the practical arrangements for the financing, engineering and construction of the units will follow, as will the establishment of a joint venture company, with CGN owning at least 51 % of the capital.

**Slovakia:** According to Slovenské Elektrárne, fuel loading into the new units of the Mochovce NPP should begin at the end of 2016/early 2017 for Unit 3, and one year later for Unit 4. The Mochovce project was hampered by delays and cost overruns due to work to meet additional safety requirements.

In December 2015, Enel Produzione S.p.A. signed a contract with EP Slovakia BV, a subsidiary of Energetický a průmyslový holding a.s., for the sale of its 66 % stake in Slovenské elektrárne, a.s. This sale is due to be implemented in two phases.

In November, Slovakia signed a Memorandum of Understanding with China providing for cooperation on developing the nuclear fuel cycle supply chain.

**Slovenia**: Slovenia and Croatia have agreed to extend the lifespan of their jointly-owned Krško NPP in Slovenia from 40 to 60 years, following the plant's good operational safety and economic results. The two countries also decided that an onsite dry storage facility for the spent fuel generated at Krško should be built.

**Finland:** The Finnish Teollisuuden Voima Oyj (TVO) utility decided not to submit a license application for the construction of a fourth reactor at the Olkiluoto NPP for the time being, due to the delay in the completion of Olkiluoto 3. The utility says that it will maintain capacities in order to be able to apply for a new decision-in-principle from the government in the future, which would require majority approval by Finland's parliament.

At the end of June, Fennovoima submitted its construction licence application for the planned Hanhikivi NPP project to the Ministry of Employment and the Economy. As regards the initial condition concerning the level of domestic ownership in the project, in August Finnish ownership of Fennovoima exceeded the requested 60 %, following further financial commitments from three domestic companies.

In November, the Finnish government granted a construction licence to the waste management company Posiva for a used nuclear fuel encapsulation plant and final disposal facility at Olkiluoto.

**Sweden**: Due to continuously low electricity rates and an increased tax on nuclear capacity in Sweden, OKG decided not to bring Unit 2 at Oskarshamn NPP, offline since June 2013, back to the grid. Unit 1 will also close earlier than planned, at a date to be communicated.

For the same reasons, Vattenfall decided to close Units 1 and 2 at the Ringhals NPP between 2018 and 2020, earlier than was previously planned (in 2025). The decision is still subject to approval by the Ringhals board of directors, and by E.ON, which has a minority stake in the two reactors. Nevertheless, Vattenfall still intends to keep its other five reactors at Ringhals and Forsmark operating through the 2040s.

The Swedish Radiation Authority approved a power uprate of the Ringhals-4 unit, in commercial operation since 1983. The approval was received after years of delay and allows for a 175 MWe increase from the reactor's current 999 MWe of installed capacity.

Forsmark Group also applied for regulatory approval in 2015, to permanently increase by 12 % the power level of Unit 2 at the Forsmark NPP. The reactor had operated at the increased power level of 1 120 MW on a trial basis for 2 years. Forsmark also intends to add 114 MWe of capacity to Unit 1.

According to the country's nuclear regulator, the operators of the four reactors that have or will shut down earlier than planned should pay higher waste fees, to ensure sufficient funds for future decommissioning activities and waste management.

In December, the licensing process for the construction of a used nuclear fuel encapsulation plant and final repository in Sweden progressed. The Land and Environment Court in Stockholm will now proceed with the review process.

**United Kingdom:** In January, EDF Energy announced that the two-unit advanced gas-cooled reactor plant at Dungeness B had received a 10-year life extension, and would continue generating electricity until 2028.

The country's only operating pressurized water reactor, Sizewell B, will be able to continue generating electricity until 2025 as the nuclear regulator approved the plant's latest periodic safety review conducted in February 2015.

In May, first batches of nuclear waste have been placed in the new low-level waste disposal facility at the Dounreay site.

In June, the United Kingdom and Canada signed a Memorandum of Understanding on enhanced cooperation in the field of civil nuclear energy.

NuGen, a nuclear new-build development consortium jointly owned by Toshiba and ENGIE, announced in July that it had signed an agreement with the United Kingdom Nuclear Decommissioning Authority to buy land at the Moorside site, near the Sellafield reprocessing centre, where NuGen plans to build three Westinghouse AP1000 reactors.

The country's other new-build project, Hinkley Point C nuclear generating station in Somerset, was in September awarded the United Kingdom Treasury's loan guarantee. According to the United Kingdom Treasury, this official guarantee of payment of the loan should facilitate the final investment decision on the part of energy companies EDF, China General Nuclear Corporation and China National Nuclear Corporation. The decision is still pending, however. In October, it was revealed that China would take a one-third stake in the project to build a new NPP at Hinkley Point in the United Kingdom and to take shares in two further plants.

At the end of December, the Wylfa plant in Wales was closed after 44 years of service, marking the end of Magnox reactor generation in the United Kingdom.

## ESA operations

### *Mandate and core activities*

The Euratom Treaty created a common nuclear market in the EU. 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 improving 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 that diversify their sources of supply in order to prevent excessive dependence of EU users on any single, third-country supply source. 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 in order 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 an EU producer selling nuclear material. 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 2015, ESA processed 375 transactions, including contracts, amendments and notifications of front-end activities, thus contributing to ensuring the security of supply of nuclear materials.

ESA's 2014 Annual Report was published on ESA's website at the beginning of July 2015. As every year, ESA presented its annual calculation of different types of average natural uranium prices: MAC-3, multiannual and spot prices. For the first time, the report was also published as an e-book ([15]).

In 2015, in line with its statutory obligations, ESA's nuclear fuel market observatory continued to send out 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 contributes to strengthening security of supply.

In 2015, ESA issued four *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 the quarterly spot-price index for natural uranium whenever three or more ordinary spot contracts have been concluded.

Following a widening of the ESA's observatory role in 2013 to cover aspects of the supply of medical radioisotopes in the EU, in 2015 ESA continued to coordinate actions undertaken to improve the security of supply of Molybdenum-99/Technetium-99m — the most vital medical radioisotope — by chairing the European Observatory on the Supply of Medical Radioisotopes set up in 2012. In addition to these activities, ESA prepared in 2015 a comprehensive report on activities following-up the three Council Conclusions on the medical radioisotopes (adopted in 2009, 2010 and 2012). The Commission adopted the report on 15 September, and on 5 October 2015 it was presented in the Council's Working Group on Atomic Questions. The report ([16]) presents the status of the implementation of responses by the EU institutions and gives an outlook on further short- and medium-term actions to be undertaken to ensure the security of supply of medical radioisotopes in the EU.

Another closely related aspect is the supply of uranium for fabrication of fuel for the European research reactors where the medical radioisotopes are produced. To that end, in close cooperation with the Member States concerned, ESA continued to set up the conditions for supplying HEU to users who still need it, in compliance with international nuclear security commitments. ESA arranged for two meetings in 2015 to discuss the implementation of the Memorandum of Understanding signed with the US DOE-NNSA in 2014, focusing on the proposed list of the excess materials that EU holders consider for the exchange.

In 2015, ESA prepared and presented to its Advisory Committee a draft proposal for updated agency Rules ([17]). If adopted, this would be the first revision since 1975. The aim is to bring the agency Rules up-to-date with current market practices.

## *Activities of the Advisory Committee*

In line with ESA's statutes, the Advisory Committee assists the Agency in carrying out its tasks by giving opinions and providing analyses and information. The Advisory Committee also acts as a link between ESA, producers and users in the nuclear industry, as well as Member State governments.

In 2015, the Advisory Committee met twice. At the first meeting (on 28 April), the main topics on the agenda were the committee's opinions on ESA's 2014 Annual Report and on ESA's audited accounts for 2014. The committee endorsed the final report of the Working Group on Prices and Security of Supply. The report ([18]) provides an updated analysis of nuclear fuel availability at EU level from a security of supply perspective. The work on the report started in 2013, and in 2014 and 2015 both the analytical and the descriptive parts were finalised. The report, which describes in detail several risk factors for the nuclear industry and contains recommendations addressed to utilities, suppliers, regulators, Member States and ESA, was published in July. It was presented to and discussed in the Council's Working Group on Atomic Questions on 5 October 2015.

During the April meeting, updates were given on:

- the European Observatory's work on the supply of medical radioisotopes ([19]);
- ESA's latest discussions on the supply of high-enriched uranium (HEU) and low-enriched uranium (LEU) for research reactor fuel;
- targets used to produce medical radioisotopes, namely in the context of the Memorandum of Understanding on HEU exchange, signed between ESA and the US Department of Energy in December 2014.

The committee endorsed the terms of reference and the list of members of the new Working Group on Intermediaries, which

([15]) http://bookshop.europa.eu/en/euratom-supply-agency-annual-report-2014-pbMJAA15001/?CatalogCategoryID=luYKABst3IwAAAEjxJEY4e5L
([16]) http://ec.europa.eu/euratom/docs/ESA-MEP-web_final %20 14.09.2015.pdf
([17]) http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31960R0511:EN:HTML, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31975R0701:EN:HTML
([18]) http://ec.europa.eu/euratom/docs/2015-ESA-MEP-rapport-web.pdf
([19]) http://ec.europa.eu/euratom/observatory_radioisotopes.html

aims to assist ESA in the assessment and definition of the policy and procedures to be applied for contracts signed by EU-based intermediary companies buying and selling nuclear materials. There was also discussion on the proposed revision of ESA's Rules and the latest developments on bilateral Euratom agreements with non-EU countries.

The second meeting took place on 22 October. The committee discussed the follow-up to the report of the Working Group on Prices and Security of Supply, the progress achieved by the Working Group on Intermediaries, and ESA's reflection paper on potential EU nuclear material reserves (reprocessed uranium from spent fuel, plutonium with uranium tails in MOX fuel and depleted uranium for re-enrichment). The proposed revision of the ESA's Rules was further discussed and an update on the work of the European Observatory on the Supply of Medical Radioisotopes was given. The committee also provided a favourable opinion on the estimate of ESA's revenue and expenditure for the 2017 financial year.

### *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 OECD Nuclear Energy Agency (NEA). In 2015, ESA continued its cooperation with both these organisations by participating in two working groups — the joint NEA/IAEA Uranium Group ([20]) and the NEA High-Level Group on the Security of Supply of Medical Radioisotopes (HLG-MR) ([21]) — as well as the Nuclear Development Committee (NDC) ([22]). It also continued to participate, on an ad hoc basis, in the working groups and nuclear fuel plenary sessions of the World Nuclear Association (WNA) ([23]). During the WNA working group meetings in September 2015, and at the joint NEA/IAEA Uranium Group meeting in November 2015, ESA presented its latest analysis of the EU nuclear market. At the HLG-MR meetings held in February and July 2015, ESA provided an update of the work of the European Observatory on the Supply of Medical Radioisotopes.

## 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 (Article 54 of the Euratom Treaty) and it operates under the supervision of the Commission (Article 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, who covers the bulk of its administrative needs (staff, offices, and minor expenses) and additionally grants ESA a financial contribution based on ESA's budget estimate.

For its financial operations, ESA applies the relevant provisions of its statutes as well as the EU financial regulation ([24]) and the accounting rules and methods established by the Commission.

### *Seat*

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

### *Financial Regulation*

ESA applies the EU Financial Regulation ([25]) — Regulation (EU, Euratom) No 966/2012 of the European Parliament and of the Council of 25 October 2012.

Article 1(2) of the EU Financial Regulation stipulates that 'this regulation shall apply to the implementation of the budget for the Euratom Supply Agency'.

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

In 2015, the assets owned by the Agency totalled EUR 643 900. They were financed by liabilities of EUR 2 646 (0.4 %) and equity of EUR 641 254 (99.6 %). 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 2015, the amount of the instalment called up and reflected in ESA's accounts stood at EUR 585 600.

In 2015, the Agency's budget slightly increased to EUR 125 000 (compared to 104 000 in 2014). 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 119 000) and by

([20]) http://www.oecd-nea.org/ndd/uranium
([21]) http://www.oecd-nea.org/med-radio/security/
([22]) http://www.oecd-nea.org/ndd/ndc/
([23]) http://www.world-nuclear.org/

([24]) 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.
([25]) Regulation (EU, Euratom) No 966/2012 of the European Parliament and of the Council.

own revenue (bank interest on the paid-up capital, for approximately EUR 6 000).

ESA's expenses consist only of administrative costs. The Agency neither manages operational budget lines nor provides grants. The bulk of the Agency's administrative expenses, including salaries, premises, infrastructure, training, and some IT equipment, is covered directly by the Commission budget, and is not acknowledged in the Agency's accounts. 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 accoSunts and are considered as non-exchange transactions for the Agency. ESA's running costs are partly covered by its own budget; this includes staff missions, IT equipment for its own computer centre, and media subscriptions.

ESA's financial statements from 31 December 2015 show a budget execution of EUR 123 650, or 99 % of commitment appropriations (against 91 % in 2014). Unused amounts are returned to the EU budget.

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

## *External audit by the Court of Auditors*

The European Court of Auditors audits ESA's operations on an annual basis. The Court's responsibility is to provide the European Parliament and the Council with a statement of assurance as to the reliability of the annual accounts and the legality and regularity of the underlying transactions.

ESA takes due account of the opinions expressed by the Court. In 2015, the Court provided an unmodified opinion on the reliability of the accounts and on the legality and regularity of the underlying transactions for the financial year 2014.

## *Discharge*

The European Parliament, acting on a Council recommendation, is the discharge authority for ESA. On 29 April 2015, the European Parliament granted ESA's Director General discharge for the implementation of the budget for the 2013 financial year ([26]).

## *Staff*

At the end of 2015, ESA had 17 permanent posts. The one contractual agent post was lost, as it was not replaced following the resignation of the jobholder. ESA staff are European Commission officials, in accordance with Article 4 of ESA's statutes ([27]).

([26]) European Parliament decision of 29.4.2015 (2014/2117(DEC), ARES(2015)2147050/22.5.2015.

([27]) 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 2015 developments affecting the global supply and demand balance and the security of supply at different stages of the fuel cycle. It relies on data collected from various specialised publications.

According to the latest industry data, there were 442 nuclear reactors operational in the world at the end of 2015, with a generation capacity of 384 GWe, able to supply approximately 11 % of the world's requirements. As compared to 2014, some additional 484 MWe of generation capacity came from reactor uprates, performed in South Korea, Sweden and the USA, while ten new units were connected to the grid in China, Russia and South Korea, corresponding to an approximate extra nuclear generation capacity of 9.3 GWe. Despite the burden of the continuing regulatory response to the Fukushima accident, nuclear power expansion continued in 2015, led by China and India. Of the 66 ongoing worldwide projects related to nuclear reactor construction, seven were launched in 2015, of which six in China and one in the United Arab Emirates.

Japan restarted its first two reactors in 2015, under the new safety guidelines adopted following the March 2011 Fukushima Daiichi accident. Also in 2015, Japan's Advisory Committee on Energy and Natural Resources approved a draft plan on the country's future energy mix, which projects that nuclear energy will hold a 20-22 % share in power generation capacity by 2030, to be ensured by restarting the nuclear power plants whose safety has been confirmed.

China continued its ambitious nuclear build programme, which aims to have 100 nuclear plants in operation by 2030, corresponding to 10 % of its electricity supply from nuclear power; this means six units entering commercial operation and construction starting on six other reactors. The country's 2015 gross nuclear generation of 168.9 billion KWh was 29.42 % higher than its 2014 output. According to a draft 13th 5-Year Plan for the power industry that covers the 2016-2020 period, nuclear power generation from reactors should reach 88 GWe by 2020, with six to eight reactors added to the grid every year.

India took further steps towards ensuring that its growing nuclear power programme advances smoothly, by signing a breakthrough uranium supply agreement with Cameco Inc. for the supply of 7.1 million pounds of $U_3O_8$ through 2020. Ten sites received the in-principle Indian governmental approval to host new nuclear builds. Latest industry estimates indicate that India will have an installed capacity of 7.4 GWe by 2017.

### *Natural uranium production*

In 2015, global uranium production increased by 8 % compared with 2014, totalling 60 773 tonnes of uranium. As in 2014, the top three uranium-producing countries were Kazakhstan, Canada and Australia.

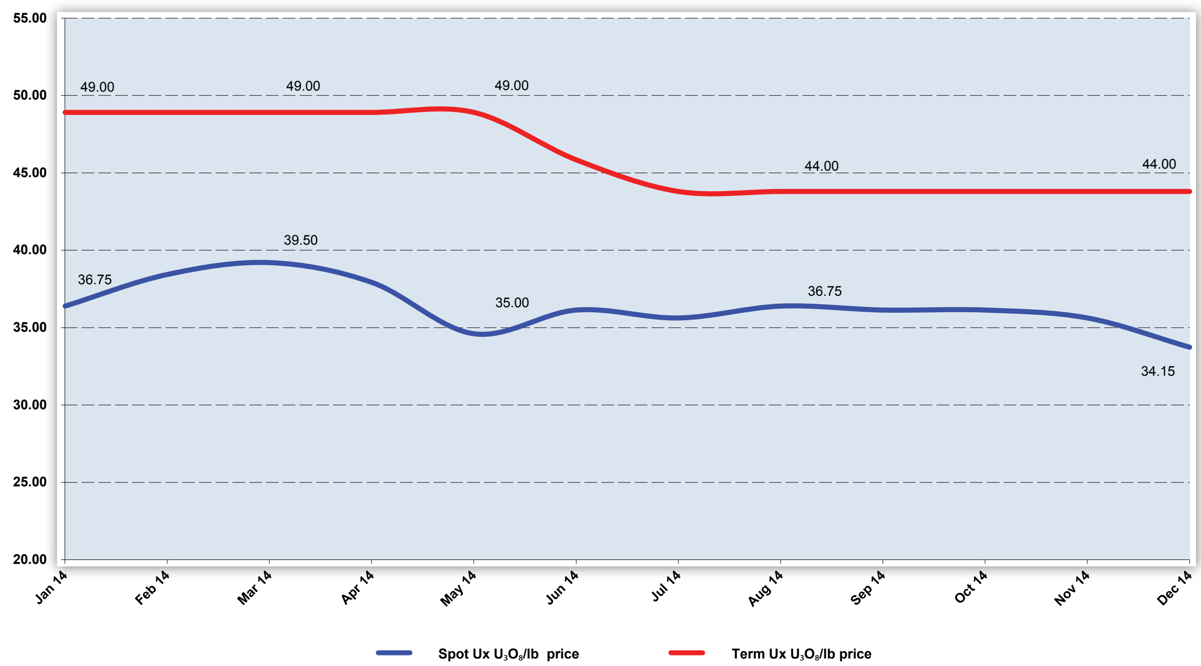
Kazakhstan remained the world's leading uranium producer in 2015, accounting for 39 % of total worldwide uranium output. The country's uranium production accounted for 23 800 tU in 2015, a 3 % increase compared to the 2014 figure. Canada's production was estimated at around 13 300 tU in 2015, a significant 46 % increase over the 2014 data, due to the Cigar Lake mine ramping up. Australia's production increased by 13 % compared to 2014, totalling 5 654 tU at the end of 2015.

**Table 2.** Natural uranium estimate production in 2015 (compared with 2014, in tonnes of uranium)

| Region/country | Production 2015 (estimate) | Production 2014 (final) | Share in 2015 (%) | Share in 2014 (%) | Change 2015/2014 (%) |
|---|---|---|---|---|---|
| Kazakhstan | 23 809 | 23 127 | 39 | 41 | **3** |
| Canada | 13 308 | 9 134 | 22 | 16 | **46** |
| Australia | 5 654 | 5 001 | 9 | 9 | **13** |
| Niger | 4 154 | 4 057 | 7 | 7 | **2** |
| Namibia | 3 039 | 3 255 | 5 | 6 | **-7** |
| Russia | 3 000 | 2 990 | 5 | 5 | **0** |
| Uzbekistan | 2 423 | 2 400 | 4 | 4 | **1** |
| United States | 1 539 | 1 919 | 3 | 3 | **-20** |
| China | 1 231 | 1 500 | 2 | 3 | **-18** |
| Others | 1 192 | 1 336 | 2 | 2 | **-11** |
| Ukraine | 1 039 | 962 | 2 | 2 | **8** |
| South Africa | 385 | 573 | 1 | 1 | **-33** |
| **Total** | **60 773** | **56 254** | **100** | **100** | **8** |

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

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




*Source:* The Ux Consulting Company.

The spot price indicator showed volatility in 2015. It started at USD 36.75 per pound and increased gradually to USD 39.50 at the end of the first quarter of 2015. In April, it started to decrease, in May falling to USD 35.00 per pound. In the second half of the year, the price ranged between USD 36.00 and USD 37.00 per pound, ending the year at USD 35.50 per pound.

The long-term indicator started the year at USD 49 per pound, but fell to USD 44 per pound by July, and stayed at this level until the end of the year.

## *Secondary sources of supply*

Secondary supply can be defined as all the materials used to meet reactor requirements, other than those coming from primary production. In 2015, 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 depleted uranium (tails) and uranium saved through underfeeding.

According to the WNA's latest industry report ([28]), depleted uranium is the largest form of potential secondary supply by mass, with more than 1.5 million tonnes at various assays stored at enrichment plants around the world. Its possible future use is manifold, including in particular re-enrichment and further fuel assembly fabrication.

It is estimated that enricher underfeeding, another significant source of secondary uranium supply, contributes up to 5 800tU of supply per year. The Fukushima-driven shutdown of Japan's nuclear power industry (light-water reactors reliant on enriched uranium), combined with new enrichment capacity no longer required, have led to significant overcapacity in the enrichment market over the past 5 years.

In recent years, secondary supply has shown a downward trend. According to various industry sources, the level of secondary sources of supply is currently at around 15 000 tU/year and is likely to remain steady at a level ranging between 10 000 to 12 000 tU/year until 2035.

## *Uranium exploration and mine development projects*

Although there are extensive uranium resources worldwide, their exploration is not sufficiently developed. However, industry estimates show that, after a long time during which secondary supply provided a considerable bulk of world reactor requirements, utilities are again looking into primary uranium markets to secure most of their long-term contracts needed to meet growing requirements. It is assumed that the identified uranium resources will be able to meet projected future requirements and nuclear power growth in the short and medium term.

The WNA concluded that exploration programmes have contributed to expanding uranium resources worldwide and, even against the background of deteriorating market conditions after 2011, uranium production increased as new production centres ramped up and almost reached their nameplate capacities. This trend has been led by Kazakhstan, who has become the world's largest uranium producer using in-situ recovery.

In 2015, development work was reported as under way at potentially important mines located in Tanzania (at the Mkuju River deposit), Turkey (Temrezli deposit), and Bangladesh (Sylhet and Moulvibazar deposits).

In March, Bannerman Resources Limited confirmed the successful completion of the construction and official opening of the Etango Heap Leach Demonstration Plant in Namibia.

In April, Cameco announced that the Australian Federal Minister for the Environment had approved Cameco and Mitsubishi Development's Kintyre uranium project in the remote East Pilbara region.

In September, Spain authorised preliminary infrastructure works at the Retortillo uranium mine project.

In October, state-owned China National Nuclear Corp. announced plans to build four new uranium mines in China, each with an annual output capacity of 1 000 tonnes of raw ore concentrates.

At the end of 2015, Cameco declared that production from the Cigar Lake mine resulted in over 10 million pounds of $U_3O_8$. By September 2015, the McClean Lake mill had already processed and packaged 6.1 million pounds of $U_3O_8$.

The US Nuclear Regulatory Commission has granted authorisation to Peninsula Energy Limited to begin in-situ uranium recovery operations at its Lance project in Wyoming. The results of preoperational inspections have indicated that in-situ recovery operations up to the ion exchange columns can be performed at this site.

Of the projects that have been delayed or deferred indefinitely, the Imouraren project in Niger is the most important, and is only due to start production in 2020. The Husab project in Namibia is reportedly on schedule to start production in 2016. Rio Tinto completely withdrew its support for any expansion of ERA's Ranger uranium mine in Australia, and therefore the rehabilitation project of the Ranger uranium mine has been put on hold. The development of the Eco Ridge rare earth and uranium mine project (in Ontario) was suspended due to poor market conditions.

([28]) *The Nuclear Fuel Report — Global Scenarios for Demand and Supply Availability 2015-2035.*

## *Conversion*

In 2015, world nameplate primary conversion capacity was estimated at around 59 000 tU. Although the actual conversion production is generally less than nameplate (according to the WNA, capacity utilisation is about 79 % of nameplate), supply provided by primary and secondary conversion sources was well above the global demand for conversion services, estimated at around 58 000 tU in 2015. Five primary conversion plants operating commercially in Canada, China, France, Russia and the United States met the majority of global demand for $UF_6$ conversion services. Part of the supply, around 12 000 tU, continued to be provided by secondary conversion sources (the same sources which displace primary uranium production).

**Table 3.** Commercial $UF_6$ conversion facilities (tonnes of uranium/year)

| Company | Nameplate capacity in 2015 (tU as $UF_6$) | Share of global capacity (%) |
|---|---|---|
| Atomenergoprom (Rosatom) (Russia) | 12 500 | 21 |
| Cameco (Canada) | 12 500 | 21 |
| ConverDyn (United States) | 15 000 | 25 |
| Comurhex (AREVA) (France) | 15 000 | 25 |
| CNNC (China) | 4 000 | 7 |
| Ipen (Brazil) | 100 | 1 |
| **Total nameplate capacity** | **59 100** | **100** |

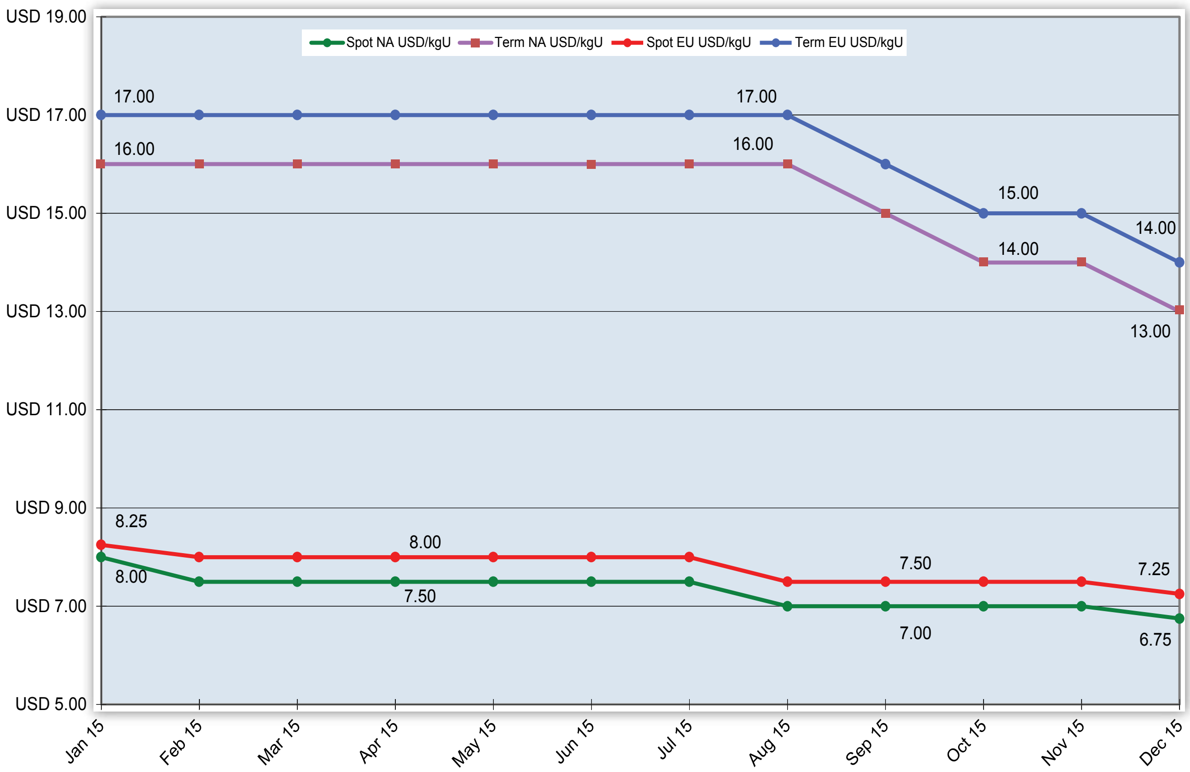
*Source: WNA, The Nuclear Fuel Report — Global Scenarios for Demand and Supply Availability 2015-2035.*

In April, $UF_6$ production at the Honeywell Metropolis conversion facility successfully resumed, following an extended 3-month maintenance shutdown, during which site resources were optimised and $UF_6$ production targets were brought in line with reduced customer demand. The facility maintains an annual nameplate capacity of 15 000 tU, while adjusting actual production rates so as to accommodate customer and market demand.

Due to current market conditions, AREVA has decided to slow down expanding the capacity at COMURHEX II and extend production from its existing facilities, which will run until 2017, following approval granted in July by the French National Safety Authority. COMURHEX II will ramp up production gradually from 2018 onwards and reach full production in 2021. Investment into the Malvesi plant has been completed and final active tests were performed in mid-2015.

With the exception of COMURHEX II, which will add 1 000 tU of annual capacity, no Western converter has firm plans to expand their conversion capacity, putting the balance between $UF_6$ supply and demand at risk. The joint Cameco-Kazakhstan project for the construction of a conversion facility in Kazakhstan has encountered continuous delays due to weak market conditions. In theory, ConverDyn could expand its production capacity, provided the market conditions are more favourable. Russia is consolidating production to one single facility, but without increased overall capacity. China seems to be the only country planning to significantly expand conversion capacity, but this is exclusively intended to meet its rapidly increasing domestic requirements.

**Figure 2.** Uranium conversion price trends (in USD)




*Source:* The Ux Consulting Company.

European and North American spot conversion prices dropped from USD 8.25 per kgU and USD 8.00 per kgU respectively, to USD 8.00 per kgU and USD 7.50 per kgU and remained stable until the end of July. In August, prices decreased again and finally finished the year at USD 7.25 per kgU in the EU and USD 6.75 per kgU in the US.

The European and North American term conversion prices showed even stronger drops than spot indices in 2015. At the beginning of 2015 they amounted to USD 17.00 per kgU and USD 16.00 per kgU, respectively, then started to drop in September, to finish the year at USD 14.00 per kgU in the EU and USD 13.00 per kgU in the US.

## *Enrichment*

In 2015, the demand for enrichment services was evaluated at around 47 000 tSW. According to the WNA's latest estimates, world enrichment requirements are expected to rise over the 2015-2030 period, reaching a level nearing 80 000 tSW by 2035. This is mainly due to new nuclear build prospects in Asian and Middle Eastern countries, particularly China and India.

The current commercial enrichment nameplate capacity of approximately 57 000 tSW is considered to be sufficient to cover demand until 2020. According to various industry-lead scenarios, projected primary supplier capacities will be more than sufficient to meet enrichment demand at least through 2025. Secondary sources (mainly downblending of HEU and use of MOX and ERU) will be available to meet world enrichment requirements beyond this date.

**Table 4.** Operating commercial uranium enrichment facilities, with approximate 2015 capacity

| Company | Nameplate capacity (tSW) | Share of global capacity (%) |
|---|---|---|
| TVEL/Tenex (Russia) | 26 600 | 47 |
| Urenco (UK/Germany/Netherlands/United States) | 19 100 | 33 |
| AREVA-GBII (France) | 7 000 | 12 |
| CNNC (China) | 4 220 | 7 |
| Others* (CNEA, INB, JNFL) | 175 | 1 |
| **World total** | **57 095** | **100** |

*Source:* WNA, *The Nuclear Fuel Report — Global Scenarios for Demand and Supply Availability 2015-2035.*
(*) CNEA, Argentina; INB, Brazil; JNFL, Japan.

Trying to overturn the current supply imbalance which has characterised the enrichment market since 2011 (caused by a drop in demand and an increase in SWU inventories), the enrichers have taken on a slower rhythm, and postponed or abandoned previously announced expansion projects.

AREVA is expected to continue to ramp up production in the GBII plant up to 7.5 million SWU by 2016 and China is expected to keep adding capacity, so as to become self-sufficient and able to cover its growing indigenous enrichment requirements. As for Urenco, capacity expansion at its New Mexico enrichment plant is pursuing at a slower pace, in line with current market conditions, and should slowly reach 5.7 million SWU by 2022. The complete expansion would increase URENCO USA's total enrichment production capacity from 3.7 million to 10 million SWU.

AREVA's Eagle Rock facility in the US and GLE's laser facility have been postponed into the next decade, at the earliest. Centrus (formerly known as USEC) continues to supply enrichment services as an intermediary.

## *Fabrication*

Fuel fabrication demand is a mixture of first cores and subsequent reloads, with an overwhelming majority of demand coming from the reload side. Nuclear fuel assemblies are highly engineered products, made to each customer's specifications, according to the type of reactor, its physical characteristics, the fuel cycle management strategy of the utility, as well as national licensing requirements. The main fuel manufacturers are also the reactor vendors, usually supplying the initial cores and early reloads for reactors of their own design. The largest fuel fabrication capacity can be found in the EU (Germany, Spain, France, Sweden and the United Kingdom), Russia and the United States, and, except for VVER fuel, each fabricator attempts to offer reloads for its competitors' reactor designs, which has led to an increasingly competitive market, especially for LWR fuel. Thus, a trend of continuously improving fuel design has emerged, as focus is given to enhanced burnups and improved performance.

In April, Ukraine renounced the Ukrainian-Russian nuclear fuel plant project under which the two countries were to build a plant for the manufacturing of VVER-1000 nuclear fuel assemblies in Ukraine. Following testing carried out over one decade, Ukraine has started using Westinghouse-fabricated VVER-1000 fuel in some of its reactors.

KEPCO Nuclear Fuel (KNF, formerly Korea Nuclear Fuel Company), which has developed its own design for Westinghouse-type reactors, is planning to build another fuel fabrication facility, to be ready for commercial operation in 2021.

## *Reprocessing and recycling*

One of the most important features of nuclear energy is that used fuel can be reprocessed to recover fissile and fertile materials in order to provide fresh fuel for existing and future nuclear power plants. Several European countries, Russia and Japan have long had a policy to reprocess used nuclear fuel, while many other countries continue to see used fuel as waste rather than a resource. The recovery of uranium and plutonium through reprocessing of spent fuel is currently carried out in France, the United Kingdom and Russia. Fabrication of the recovered material for further use in reactors requires dedicated conversion, enrichment and fabrication facilities.

So far, some 90 000 tonnes of used fuel from commercial power reactors (of 290 000 tonnes discharged) have been reprocessed. Annual reprocessing capacity is now at about 4 500 tonnes per year for normal oxide fuels, but not all of it is operational.

In 2015, the US Department of Energy conducted a review of the MOX fuel fabrication plant project and of alternatives for disposing of surplus weapons-grade plutonium. Funding for the project has been reduced and the budget proposal for the 2017 fiscal year calls for termination of the MOX project. A final decision on this is still pending.

Russia has not yet developed commercial capacities to recycle Pu as MOX in LWRs. Instead, Rosatom continues to conduct R & D on the REMIX (regenerated mixture of uranium and plutonium oxides) fuel, trying to create a closed nuclear fuel cycle, evolving around the BN-800 fast neutron reactor.

In October, AREVA took steps towards increasing its production capacity at the Melox MOX fuel plant in Marcoule, by commissioning a second powder mixing line.

In November, Japan Nuclear Fuel Ltd (JNFL) announced that there have been additional delays in the completion of the reprocessing and MOX fuel fabrication plant of Rokkasho-mura, which is now not expected to be operational before mid-2019.

It is anticipated that the use of RepU (as ERU- enriched reprocessed uranium fuel assemblies) and plutonium (in MOX fuel) will still play a role in meeting the demand for nuclear fuel, as a replacement for fresh LEU in the supply mix of European, Russian and Japanese utilities, and will save more than 1 700 tU/year after 2017. To date, there are significant stocks of plutonium worldwide and countries like the USA, Russia, Japan and China are considering additional fabrication capacity for MOX fuel. Due to the complex nature of the required upstream reprocessing of used nuclear fuel, the latest industry estimates indicate that, over the 2015-2035 period, MOX and ERU are not going to contribute more than around 2 million SWU/year to total SWU supply worldwide ([29]). Moving to fourth-generation fast neutron reactors in the late 2020s might mean that not only used fuel from today's reactors but also the large stockpiles of depleted uranium (from enrichment plants, about 1.5 million tonnes in 2015) could become a usable resource.

([29]) WNA, *The Nuclear Fuel Report — Global Scenarios for Demand and Supply Availability 2015-2035.*

# 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 2015, there were 128 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, EU-28 gross electricity generation amounted to 876.3 TWh in 2014 and nuclear gross electricity generation accounted for 27.5 % of total EU-28 production ([30]).

## Fuel loaded into reactors

In 2015, 2 230 tU of fresh fuel was loaded into commercial reactors in the EU-28. It was produced using 16 235 tU of natural uranium and 303 tU of reprocessed uranium as feed, enriched with 11 851 tSW. The quantity of fresh fuel loaded increased by 3 % (i.e. 66 tU more than in 2014). In 2015, the fuel loaded into EU reactors had an average enrichment assay of 3.82 %, falling mostly between 3.04 % and 4.61 %. The average tails assay was 0.24 %, falling mostly between 0.23 % and 0.26 %.

In 2015, MOX fuel was used in a number of reactors in Germany, France and the Netherlands. The amount of MOX fuel loaded into NPPs in the EU totalled 10 780 kg Pu in 2015, a 7 % decrease over the 11 603 kg Pu used in 2014. Use of MOX resulted in estimated savings of 1 050tU and 742 tSW (see Annex 5).

When the whole amount of fuel loaded into the EU reactors in 2015, including natural uranium feed, reprocessed uranium and MOX fuel, is added up, we get the figure of 17 380 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 use of MOX fuel and reprocessed uranium gives the amount of feed material coming from indigenous and secondary sources. All this provides for about 10 % of the EU's annual natural uranium requirements.

([30]) Eurostat Energy Statistics, 2014, Energy statistics.

## Table 5. Natural uranium included in fuel loaded by source in 2015

| Source | Quantities (tU) | Share (%) |
|---|---|---|
| Uranium originating outside the EU | 15 835 | 90.0 |
| Uranium originating in the EU (approximate annual production) | 400 | 2.3 |
| Reprocessed uranium | 303 | 1.7 |
| Savings from MOX | 1 050 | 6.0 |
| **Total annual requirements** | **17 587** | **100** |

## Future reactor requirements (2016-2035)

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 (only projects in an advanced stage of construction), lifetime extensions, the early retirement of reactors, phasing-out or decommissioning. Net requirements are calculated based on gross reactor requirements after subtracting savings resulting from planned uranium/plutonium recycling and inventory usage.

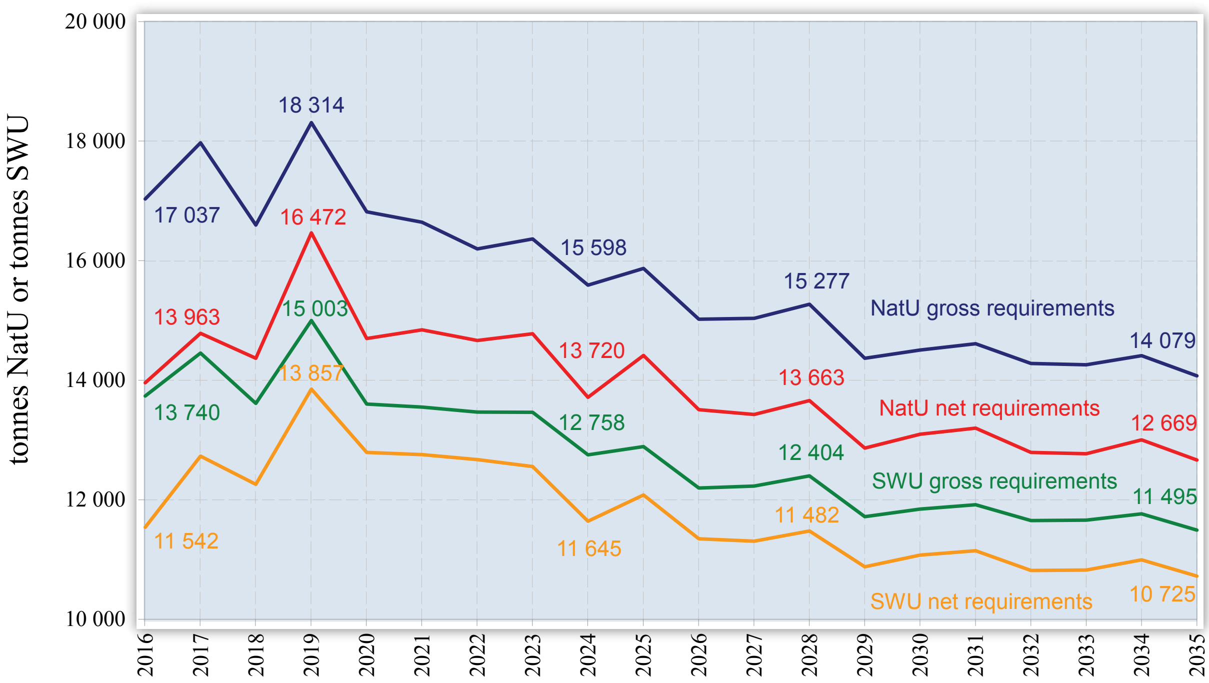
| Natural uranium — average reactor requirements | | |
|---|---|---|
| 2016-2025 | 16 745 tU/year (gross) | 14 674 tU/year (net) |
| 2026-2035 | 14 588 tU/year (gross) | 13 103 tU/year (net) |

| Enrichment services — average reactor requirements | | |
|---|---|---|
| 2016-2025 | 13 657 tSW/year (gross) | 12 492 tSW/year (net) |
| 2026-2035 | 11 890 tSW/year (gross) | 11 063 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 2016-2025, forecasts of average gross requirements for natural uranium have fallen by 5 % (-890 tU) and for separative work by 4 % (-544 tSW). For 2026-2035, the drop in demand for gross natural uranium is calculated at 1 % (-191 tU) and for enrichment services at 2 % (-225 tSW).

Figure 3. Reactor requirements for uranium and separative work in the EU-28 (in tonnes NatU or SWU)



## Supply of natural uranium

### *Conclusion of contracts*

In 2015, ESA processed a total of 115 contracts and amendments, of which 88 (77 %) were newly concluded contracts. Out of 62 new purchase/sale contracts, 37 % involved EU utilities and the remainder were signed by intermediaries. Table 6 gives further details on the kinds 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 2015 | Number of contracts concluded in 2014 |
|---|---|---|
| **Purchase/sale by an EU utility/user** | **23** | **25** |
| — multiannual (1) | 9 | 9 |
| — spot (1) | 14 | 16 |
| **Purchase/sale by intermediaries** | **39** | **23** |
| — between intermediaries (2) (multiannual) | 3 | 4 |
| — between intermediaries (2) (spot) | 36 | 19 |
| **Exchanges and loans (3)** | **26** | **11** |
| **Amendments** | **27** | **22** |
| **Total (4)** | **115** | **81** |

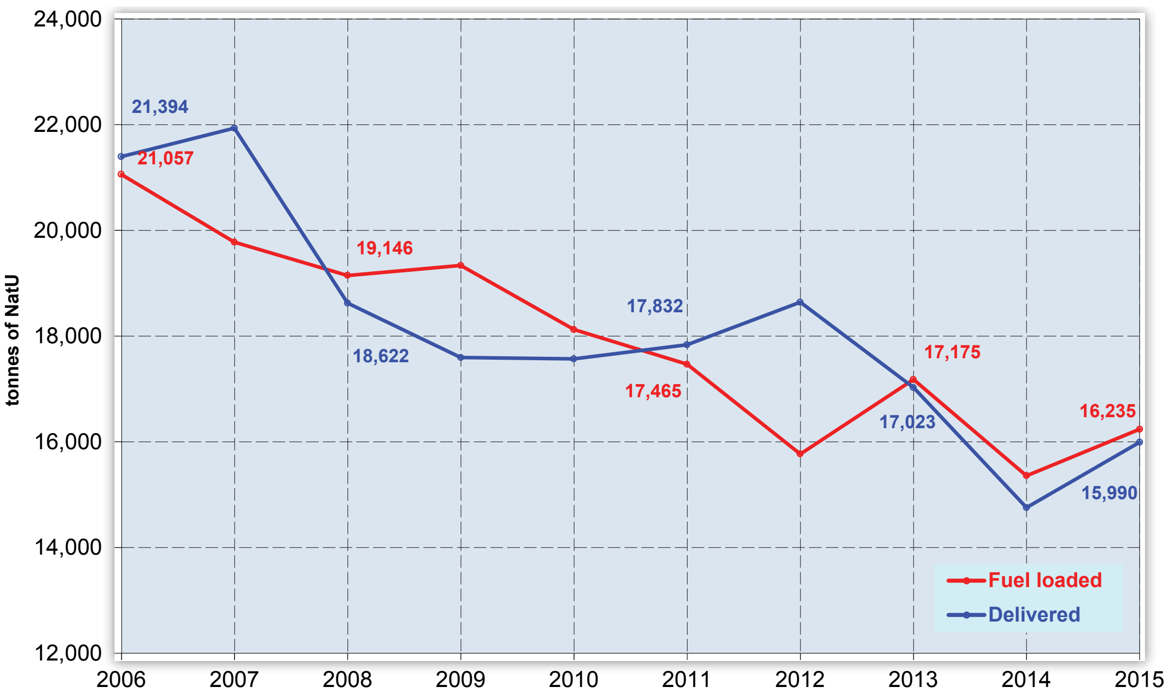
(1) Multiannual contracts are contracts providing for deliveries extending over more than 12 months, whereas spot contracts provide either for only one delivery or for deliveries over a maximum of 12 months, whatever the time between conclusion of the contract and the first delivery.

(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 exchanges of $U_3O_8$ against $UF_6$. Exchanges of safeguard obligation codes and international exchanges of safeguard obligations are not included.

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

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



### *Volume of deliveries*

The deliveries taken into account are those to EU utilities or their procurement organisations in 2015, excluding research reactors. Also taken into account is the natural uranium equivalent contained in enriched uranium purchases, when stated.

In 2015, demand for natural uranium in the EU represented approximately one third of global uranium requirements. EU utilities purchased a total of 15 990 tU in 144 deliveries under long-term and spot contracts, which is 1 239 tU or 8.4 % more than in 2014. 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 15 144 tU (of which 14 290 tU with reported prices) or 95 % of total deliveries, whereas the remaining 5 % (846 tU) was purchased under spot contracts. On average, the quantity of natural uranium delivered was 115 tU per delivery under long-term contracts and 65 tU per delivery under spot contracts.

Natural uranium contained in the fuel loaded into reactors in 2015 totalled 16 235 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 1980-2015).

### *Average delivery prices*

In order to enhance market transparency, each year ESA publishes 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, 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.

Since uranium is priced in US dollars, fluctuation of the EUR/USD exchange rate influences the level of the price indices calculated. The annual average ECB EUR/USD rate in 2015 stood at 1.11. Depreciation of the EUR exchange rate against USD resulted in an increase of ESA spot $U_3O_8$ and long-term $U_3O_8$ prices denominated in euros. This happened while USD-denominated prices for the two indices did not move substantially. The depreciation of the euro also reduced the fall of the EUR-denominated ESA 'MAC-3' price index, which only fell significantly when expressed in USD.

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

| **1. ESA spot $U_3O_8$ price: the weighted average of $U_3O_8$ prices paid by EU utilities for uranium delivered under spot contracts in 2015 was calculated as:** | |
|---|---|
| EUR 88.73/kgU contained in $U_3O_8$ | (19 % up from EUR 74.65/kgU in 2014) |
| USD 37.87/lb $U_3O_8$ | (1 % down from USD 38.15/lb $U_3O_8$ in 2014) |

| **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 2015 was calculated as:** | |
|---|---|
| EUR 94.30/kgU contained in $U_3O_8$ | (20 % up from EUR 78.31/kgU in 2014) |
| USD 40.24/lb $U_3O_8$ | (0.5 % up from USD 40.02/lb $U_3O_8$ in 2014) |

| **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 3 years and under which deliveries were made in 2015, was calculated as:** | |
|---|---|
| EUR 88.53/kgU contained in $U_3O_8$ | (5 % down from EUR 93.68/kgU in 2014) |
| USD 37.78/lb $U_3O_8$ | (21 % down from USD 47.87/lb $U_3O_8$ in 2014) |

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 2015, the ESA $U_3O_8$ spot price was EUR 88.73/kgU (or USD 37.87/lb $U_3O_8$), 19 % higher than in 2014. Price data were widely distributed, mostly falling within the range of EUR 78.05 to EUR 99.16/kgU (USD 33.31 to USD 42.32/lb $U_3O_8$).

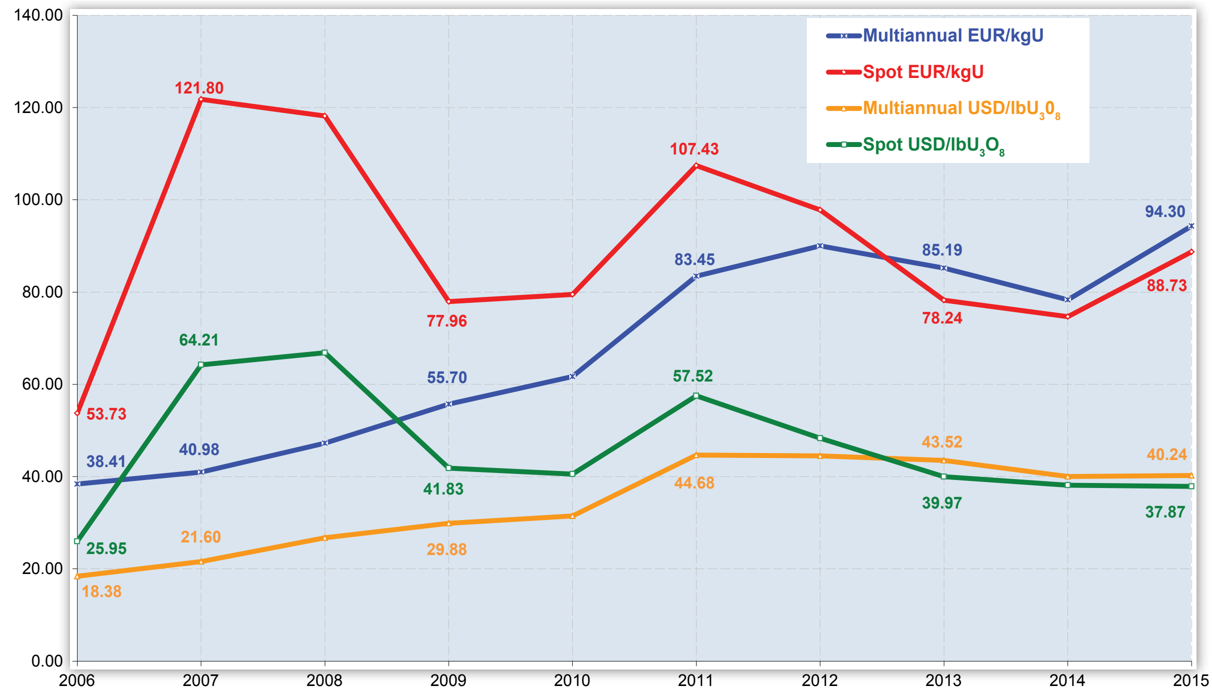
The ESA long-term $U_3O_8$ price was EUR 94.30/kgU $U_3O_8$ (USD 40.24/lb $U_3O_8$). Long-term prices paid varied widely, with approximately 75 % (assuming a normal distribution) falling within the range of EUR 72.14 to EUR 117.68/kgU (USD 30.79 to USD 50.22/lb $U_3O_8$). Usually, traded long-term prices 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 based on 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 2015 were signed 7 years earlier. The ESA long-term $U_3O_8$ price paid for uranium originating in the CIS was approximately 4 % higher than the price for uranium of non-CIS origin.

The 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 76.08 and EUR 115.83/kgU (USD 32.47 to USD 49.43/lb $U_3O_8$). The ESA MAC-3 index takes into account only long-term contracts signed recently (2013-2015) 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 6 % lower than the price for uranium of non-CIS origin.

Figure 5 shows the ESA average prices for natural uranium since 2006. The corresponding data are presented in Annex 3.

**Figure 5. Average prices for natural uranium delivered under spot and multiannual contracts, 2006-2015 (EUR/kgU and USD/lb $U_3O_8$)**




## *Origins*

In 2015, 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 2014. With regard to four big uranium-producing regions (the CIS, North America, Africa and Australia), deliveries from North America and the CIS increased and from Africa and Australia dropped slightly in 2015.

## Table 7. Origins of uranium delivered to EU utilities in 2015 (in tonnes)

| Mining origin | Quantity | Share (%) | Change in quantities 2015/2014 (%) |
|---|---|---|---|
| Russia | 4 097 | 25.6 % | 54.7 % |
| Kazakhstan | 2 949 | 18.5 % | -25.2 % |
| Canada | 2 845 | 17.8 % | 53.3 % |
| Niger | 2 077 | 13.0 % | -4.4 % |
| Australia | 1 910 | 12.0 % | -4.2 % |
| Uzbekistan | 526 | 3.3 % | 44.1 % |
| EU | 412 | 2.6 % | 3.9 % |
| Namibia | 385 | 2.4 % | 18.4 % |
| United States | 343 | 2.2 % | -41.4 % |
| Others | 229 | 1.4 % | -23.5 % |
| Re-enriched tails | 212 | 1.3 % | 100.0 % |
| Malawi | 2 | 0.0 % | -98.6 % |
| South Africa | 1 | 0.0 % | -93.1 % |
| **Total** | **15 990** | **100.0 %** | **8.4 %** |

Russia replaced Kazakhstan in first place and Canada took third place among the biggest suppliers. The top two countries delivered more than 44 % of total natural uranium delivered to the EU. Uranium originating in Russia represented the largest proportion, with 4 097 tU or 25.6 % of total deliveries (including purchases of natural uranium contained in EUP), which was 54.7 % up on 2014. This was followed by uranium originating in Kazakhstan, which had a 18.5 % share or 2 949 tU, a year-on-year decrease of more than 25 %.

In third place, uranium mined in Canada amounted to 2 845 tU or 17.8 %, a more than 53 % increase over 2014. Niger and Australia accounted for 13 % and 12 % in 2015, respectively, a decrease of more than 4 % in both cases.

Natural uranium mined in the CIS (Russia, Kazakhstan and Uzbekistan) accounted for 7 785 tU or 48.7 % of all natural uranium delivered to EU utilities, a 11.6 % increase from the year before.

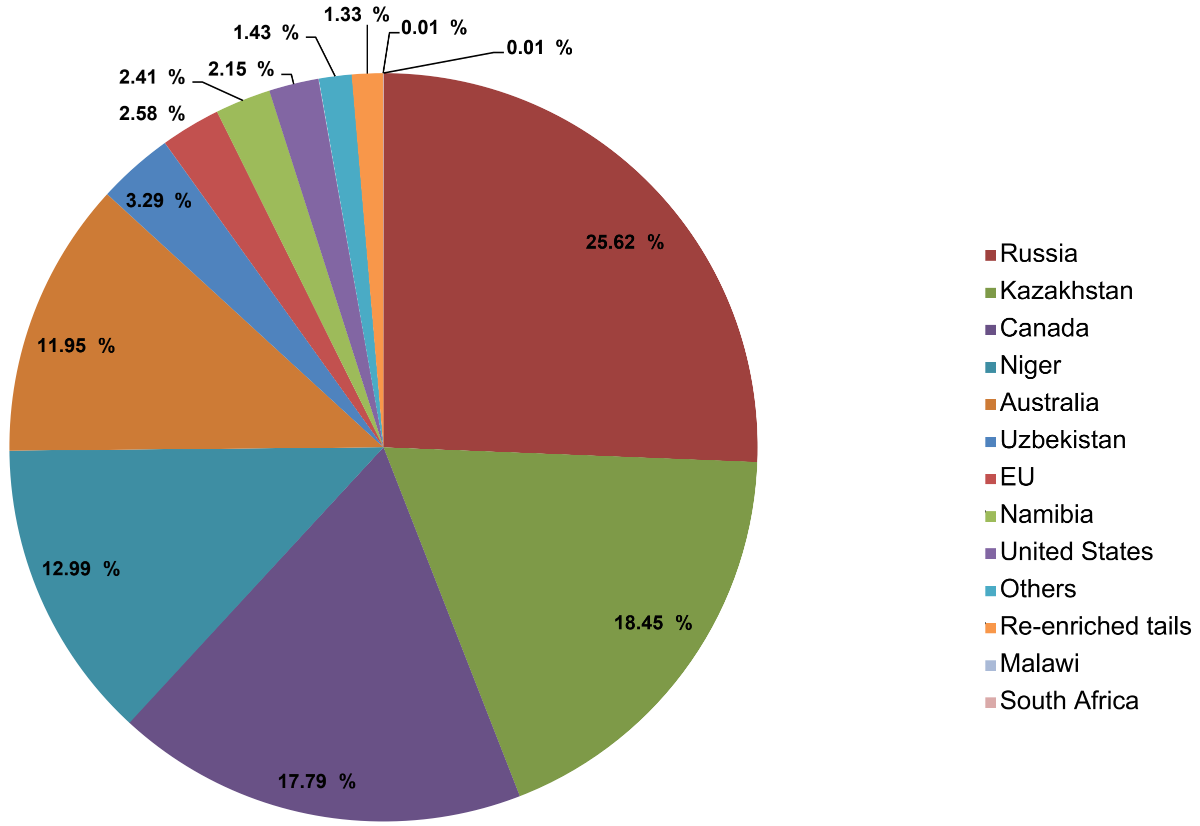
Deliveries of uranium of North American origin totalled 3 188 tU (almost 20 %), an increase of 30.6 % from 2014. Uranium of Canadian origin accounted for 2 845 tU (17.8 %).

Deliveries of uranium from Africa decreased by more than 6.7 %, down to 2 465 tU from 2 641 tU in 2014. A decrease was reported in deliveries of uranium extracted in all African producer countries except Namibia, which reported a more than 18 % increase of uranium produced in the country and delivered to EU utilities in 2015.

European uranium delivered to EU utilities originated in the Czech Republic and Romania and covered 2.6 % of the EU's total requirements (a total of 412 tU), which is about 4 % up compared to 2014.

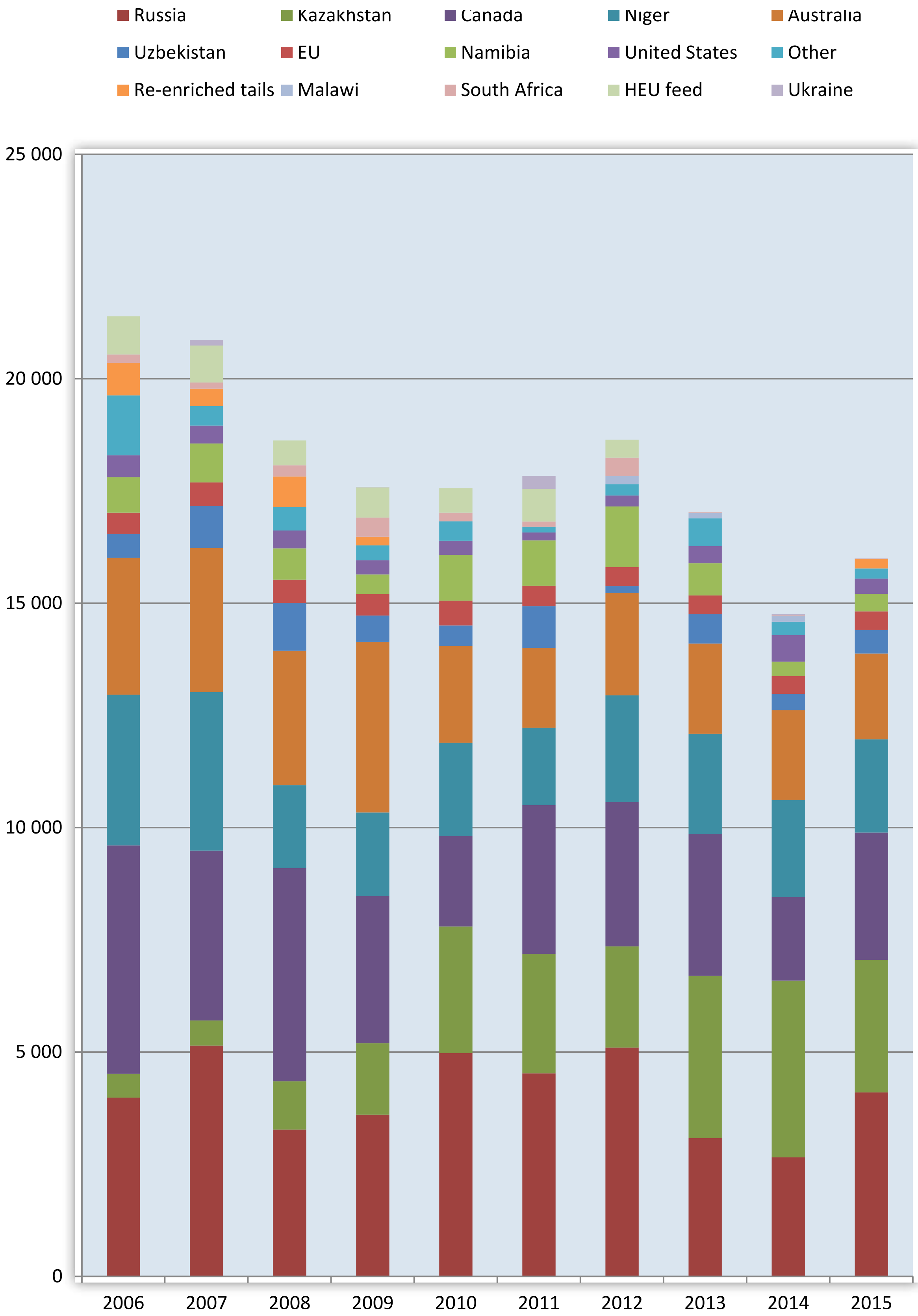
EU utilities also reported small deliveries of re-enriched tails material.

## Figure 6. Origins of uranium delivered to EU utilities in 2015 (% share)




Totals may not add up due to rounding.

Figure 7. Purchases of natural uranium by EU utilities, by origin, 2006-2015 (tU)



## Special fissile materials

### *Conclusion of contracts*

Table 8 shows the aggregate number of contracts, notifications and amendments([31]) relating to special fissile materials (enrichment services, enriched uranium and plutonium) handled in 2014 and 2015 in accordance with ESA's procedures.

### *Deliveries of low-enriched uranium*

In 2015, the enrichment services (separative work) supplied to EU utilities totalled 12 493 tSW, delivered in 1 989 tonnes of low-enriched uranium (tLEU) which contained the equivalent of 16 090 tonnes of natural uranium feed. In 2015, enrichment service deliveries to EU utilities decreased by 3 % as compared with 2014, with NPP operators opting for an average enrichment assay of 4.17 % 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 2015 | Number of contracts concluded/notifications acknowledged in 2014 |
|---|---|---|
| A. Special fissile materials | | |
| New contracts | 33 | 29 |
| Purchase (by an EU utility/user) | 7 | 6 |
| Sale (by an EU utility/user) | 7 | 5 |
| Purchase/sale (between two EU utilities/end users) | 4 | 4 |
| Purchase/sale (intermediaries) | 7 | 9 |
| Exchanges | 6 | 5 |
| Loans | 2 | 0 |
| Contract amendments | 23 | 36 |
| **Total** ([1]) | **56** | **65** |
| B. Enrichment notifications ([2]) | | |
| New notifications | 17 | 11 |
| Notifications of amendments | 12 | 5 |
| **Total** | **29** | **16** |

([1]) In addition, there were transactions for small quantities (as under 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 2015 (tSW) | Share in 2015 (%) | Quantities in 2014 (tSW) | Share in 2014 (%) | Change in quantities 2015/2014 (%) |
|---|---|---|---|---|---|
| AREVA/GBII and Urenco (EU) | 7 538 | 60 % | 8 503 | 68 % | -11 % |
| Tenex/TVEL (Russia) | 4 145 | 33 % | 3 197 | 26 % | 30 % |
| Russian blended ([1]) | 610 | 5 % | 624 | 5 % | -2 % |
| USEC(United States) | 200 | 2 % | 200 | 2 % | 0 % |
| **Total** ([2]) | **12 493** | **100 %** | **12 524** | **100 %** | **0 %** |

([1]) Including enriched reprocessed uranium.

([2]) Totals may not add up due to rounding.

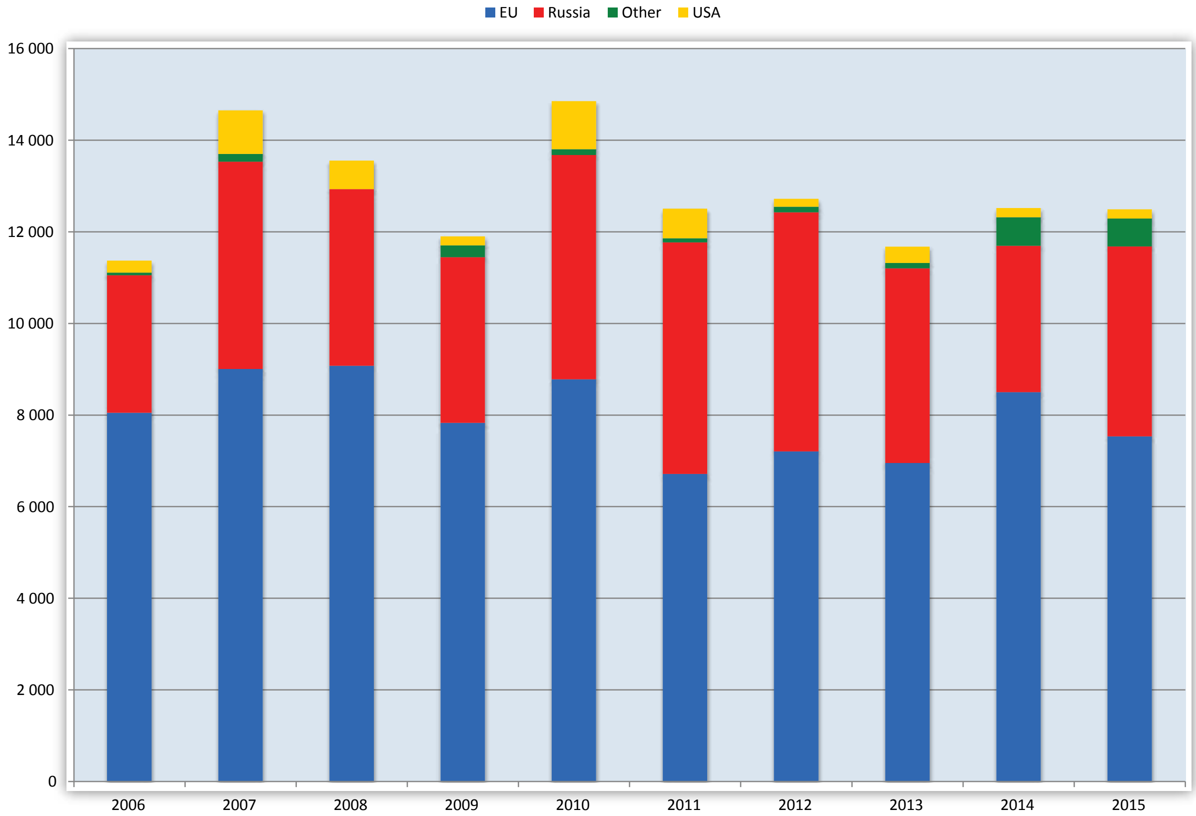
([31]) The aggregate number of amendments includes all the amendments to existing contracts processed by ESA, including technical amendments that do not necessarily lead to substantial changes in the terms of existing agreements.

As regards the providers of enrichment services, 60 % of EU requirements were met by the two European enrichers (AREVA-GBII and Urenco), totalling 7 538 tSW, a decrease 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 4 145 tSW, which accounts for 33 % of total deliveries. The aggregate total includes SWUs delivered under contracts 'grandfathered' under Article 105 of the Euratom Treaty, which covered 8 % of total EU requirements. The fuel supply contracts concluded before accession to the EU remained in force. Russian enrichment services delivered under regular contracts accounted for 26 % of total requirements.

Enrichment services provided by USEC stayed at the same level as in the previous year, totalling 200 tSW and accounting for 2 % of total enrichment services supplied to EU utilities.

## Figure 8. Supply of enrichment to EU utilities by provider, 2006-2015 (tSW)



## *Plutonium and mixed-oxide fuel*

Mixed-oxide (MOX) fuel is produced by mixing uranium and plutonium (Pu) 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 must 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 10 780 kg Pu in 2015, a 7 % decrease over the 11 603 kg Pu used in 2014.

## *Inventories*

At the end of 2015, uranium inventories owned by EU utilities totalled 51 892 tU, a decrease of 2 % from the end of 2014 and an increase of 14 % compared to the level at the end of 2010. 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, 2010-2015 (in tonnes)**

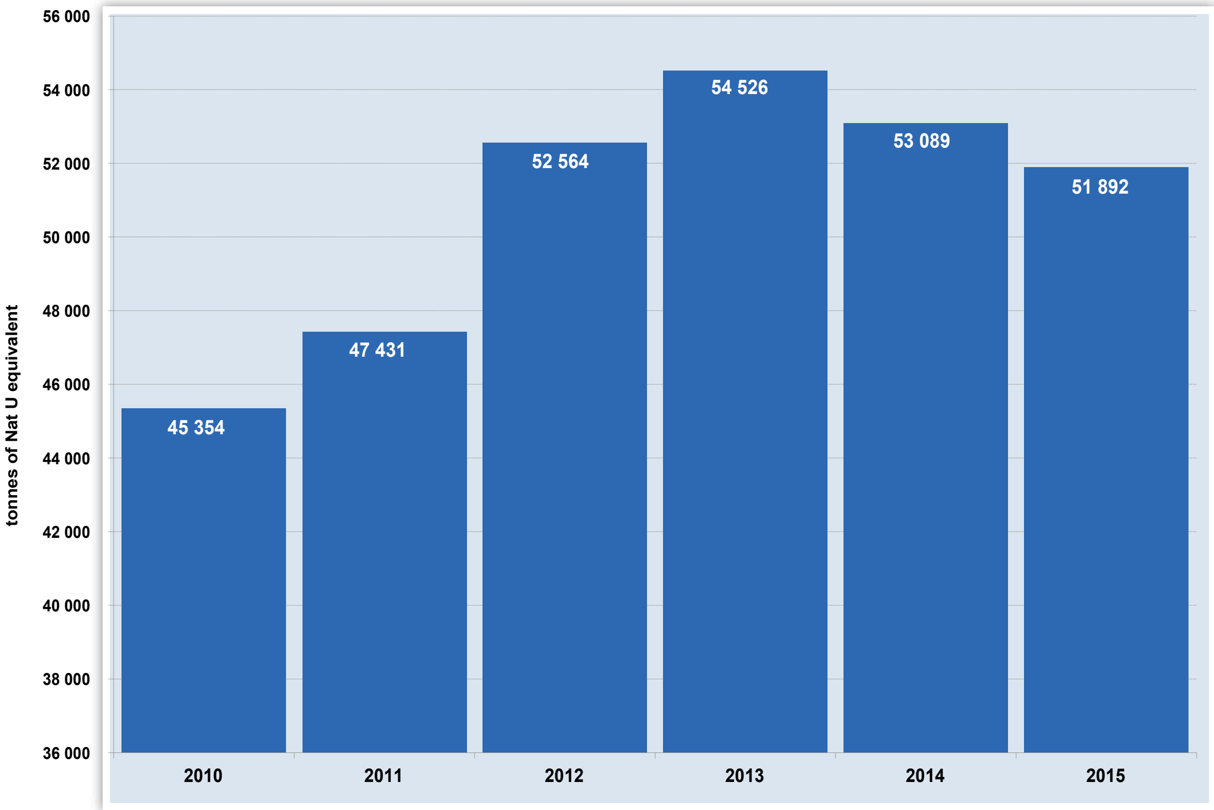



Figure 9 shows the level of total uranium inventories owned by EU utilities at the end of the year, expressed as natural uranium equivalents.

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 for 3 years on average. Most utilities keep a sufficient quantity of inventories for at least one reload.

## *Future contractual coverage rate*

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

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

As regards net reactor requirements (the denominator), a distinction is made between demand for natural uranium and demand for enrichment services. Average net reactor requirements for 2016-2025 are estimated at approximately 15 000 tU and 12 500 tSW per year, respectively (see table on page 25).

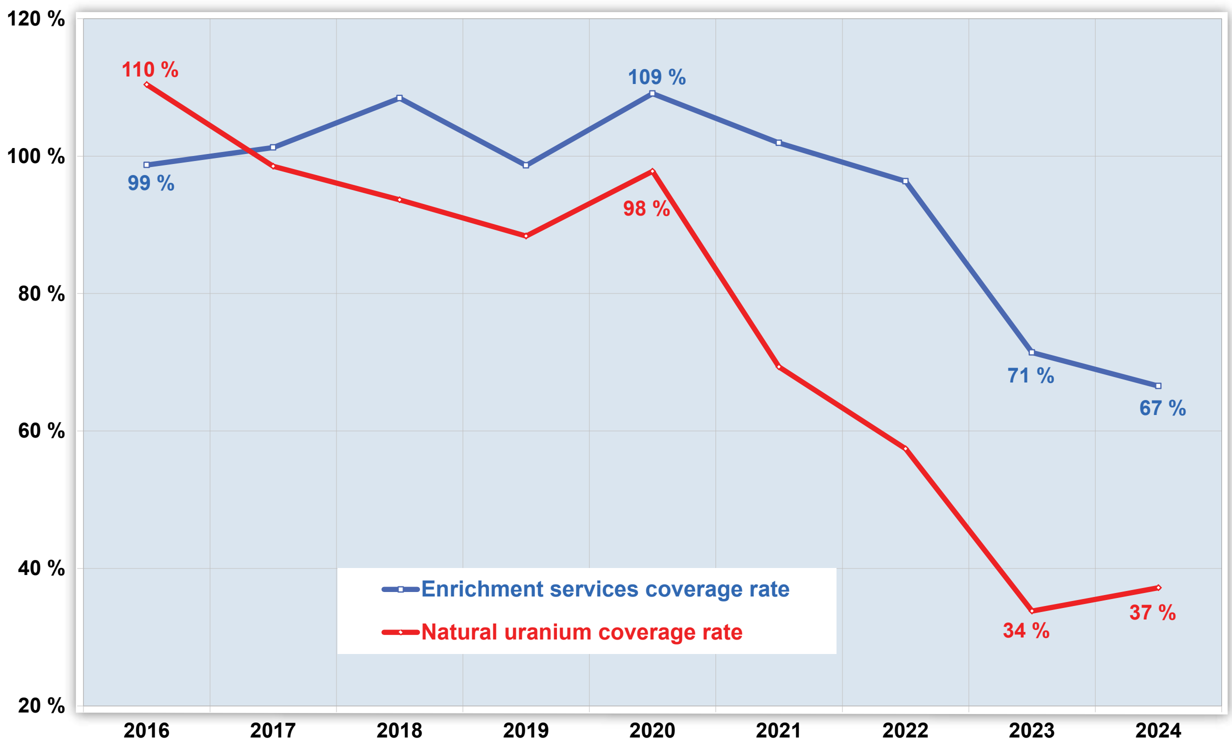
Quantitative analysis shows that EU utilities are covered well above their estimated net reactor requirements (about 100 %) until 2018, in terms of both natural uranium and enrichment services, under already-signed contracts.

For natural uranium, supply is guaranteed in 2016-2017 with a contractual coverage rate of over 100 % in 2016 and slightly under in 2017. In the long term, the uranium coverage rate will remain above 80 % until 2020, dropping below 40 % in 2023.

Enrichment service supply is well secured until 2022, with contractual coverage ranging from 96 % to 109 %, dropping to 70 % in 2023.

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, 2016-2024 (%)




## ESA findings, recommendations and diversification policy

Each year, ESA continues to monitor the market, in particular 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, in 2015 deliveries of natural uranium to the EU under long-term contracts accounted for 95 % of total deliveries. As regards mining origin, the relative shares of individual producer countries changed in comparison with the previous year, with Russia, Kazakhstan, Canada, Niger and Australia together providing almost 87 % of the natural uranium delivered to the EU. In 2015, uranium deliveries originating from Africa decreased by 7 % and from Australia by 4 %. There was an increase in deliveries of uranium of CIS and North American origin (up 12 % and 31 %, respectively), while EU-origin deliveries increased by 4 % compared with the previous year. Overall, deliveries of natural uranium to EU utilities are well diversified, though some utilities still buy their natural uranium from only one supplier.

For the diversification of sources of supply of enriched uranium to EU utilities, 60 % of the SWUs delivered in 2015 were provided by the two European enrichment companies, AREVA-GBII and Urenco. The remaining services were delivered mostly by Russia's Tenex/TVEL (33 %), and by the American company USEC (2 %), which emerged after reorganisation in 2013 as Centrus Energy Corporation and sells Russian-origin SWUs.

In 2015, deliveries of enrichment services remained almost at the same level as in the previous year. The two European enrichers decreased their relative share in the EU market by 8 %. Out of the 33 % of Russian-origin SWUs, contracts 'grandfathered' under Article 105 of the Euratom Treaty accounted for 8 % of total deliveries. In practice, 'grandfathered' contracts keep certain EU utilities entirely dependent on a single external supplier ([32]).

ESA welcomes the use of reprocessed uranium, 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 reprocessed uranium with HEU of military origin is conducive to nuclear disarmament and the non-proliferation of nuclear materials. ESA therefore takes account of these positive aspects of reprocessed fuel use when implementing its diversification policy. HEU downblended with reprocessed uranium and re-enriched reprocessed uranium fuel accounted for the equivalent of approximately 5 % of total enrichment services delivered in 2015.

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 2015 totalled 51 892 tU, which could fuel EU utilities' nuclear power reactors for 3 years on average. 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 2015, ESA concluded 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 about the full dependence on one single supplier for VVER fuel fabrication, due to a lack of alternative supply sources.

([32]) 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 sources, whereas utilities using Russian technology usually purchase fabricated fuel assemblies from a single supplier under the same contract (including supply of uranium and enrichment).

# 4. Security of supply

## Introduction

Since 2011, global demand and, consequently, the prices of natural uranium and fuel cycle services have substantially decreased. On the other hand, exploration and mine development started during the rising market in 2005-2007 has led to increased mine output, in particular in Kazakhstan. The current downturn has not yet led to a significant reduction in mining although some projects have been mothballed and some expansions delayed.

The current global overcapacity in the enrichment market has led to the development of 'virtual mining', where enrichment companies underfeed their plants and thus save natural uranium which can then be sold on the market.

For the time being, high inventory levels and modest global NPP capacity growth are delaying the recovery. On the surface, it would seem that security of supply is not an issue in today's market. However, as the nuclear industry operates with very long cycles, one should never become too complacent about this.

## Security of supply and ESA's diversification policy

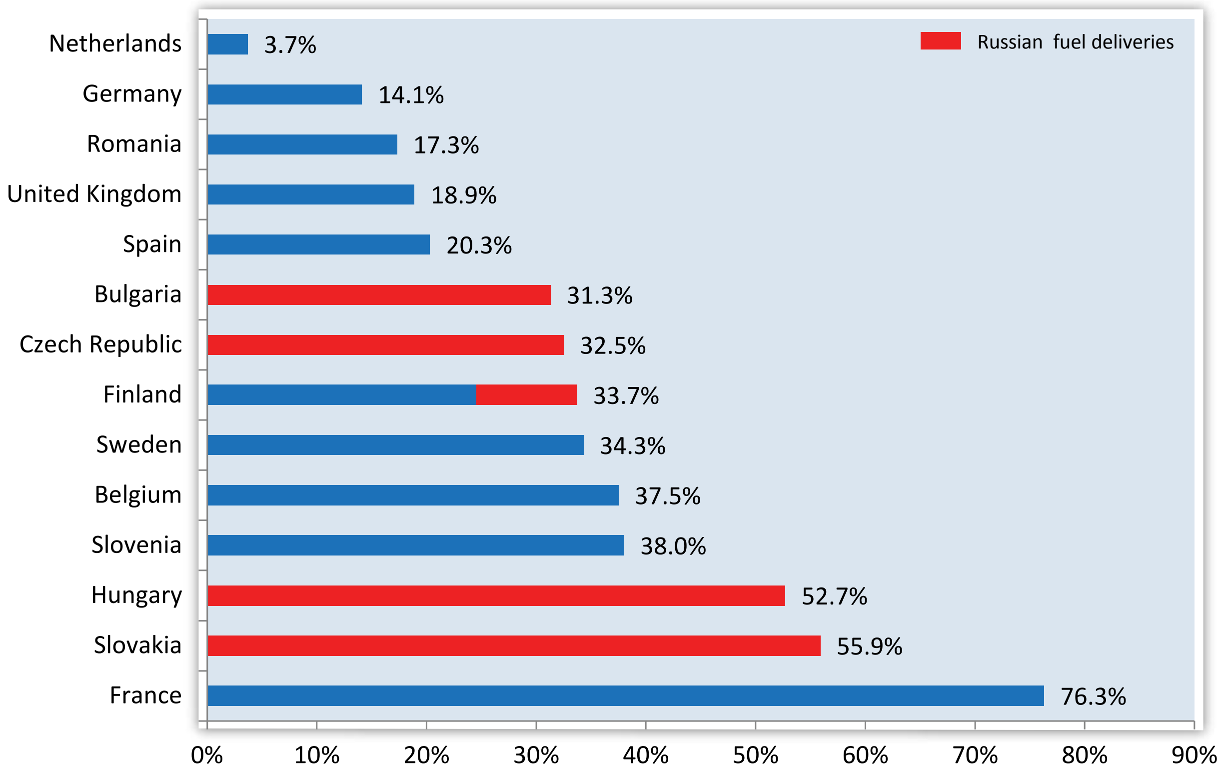
For NPP operators, the main issue after safety is still ensuring a continuous availability of fuel and the prevention of supply disruptions. Since nuclear energy provides close to 30 % of the EU's electricity, securing its supply is very important. Diversification is a key pillar of security of supply, for nuclear as for other energy sources.

ESA continues to monitor the market in order to ensure that EU utilities have diverse supply sources and do not become over-dependent on any single external source as this could jeopardise the security of supply in the medium and long term. 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 individual EU utilities remain 100 % dependent on one external supplier. In such cases, the share of nuclear in the energy mix of the Member State in which the utility is located, the Member State's potential electricity exports to neighbouring Member States, and its capacity to import electricity in case of need must all be taken into account in order to evaluate the overall risk for stable electricity supply.

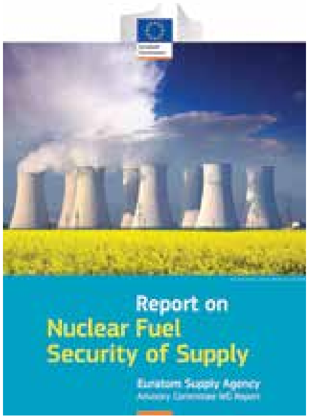
In its market-monitoring role, ESA is responsible for the early identification of market trends likely to affect the medium- and long-term security of supply of nuclear materials and services in the EU, both at aggregate EU level and for individual utilities.

**Figure 11. Nuclear power share of total electricity production in the EU, 2015 (%)**



ESA must make use of its powers under Chapter 6 of the Treaty if

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




In 2015, the ESA Advisory Committee working group on prices and security of supply finalised a report on security of supply. One of the report's general conclusions is that the security of supply of nuclear fuel to EU utilities is maintained, but there are aspects which could be improved and the global market situation should continue to be carefully monitored.

## Supply side — assessment of the global situation

Natural uranium production has increased in recent years. Together with existing secondary sources of supply (HEU down blending, RepU and Pu use in MOX fuel, underfeeding, tails re-enrichment), it covers current global power reactor requirements. When global demand recovers (e.g. to pre-2011 level), global production can be expected to adapt so as to cover possible shortfalls in the medium term, while currently plentiful inventories would most likely be enough to cover any short-term needs. Over a longer period of time, demand, prices and fresh mining production are expected to increase. According to the latest NEA-IAEA Red Book ([33]), identified global uranium resources are sufficient so as to cover current demand for at least 120 years, and many so far unexplored areas of the world may hold very significant additional resources (e.g. Greenland).

Conversion remains a potentially weak link in the nuclear fuel supply chain. The conversion industry usually suffers from low spot prices and limited long-term contracting activity as a result of secondary supplies and large stockpiles. As a consequence, there is no incentive for producers to invest in capacity expansion to overcome regional imbalances between Europe and North America, and some facilities have recently been decommissioned without replacement. Strategic inventories are helpful to mitigate symptoms of supply failure but they cannot heal the root cause of it. Utilities may be well advised to consider sharing the risk and some of the costs with converters, for the sustainability of the smallest but important step in the fuel chain.

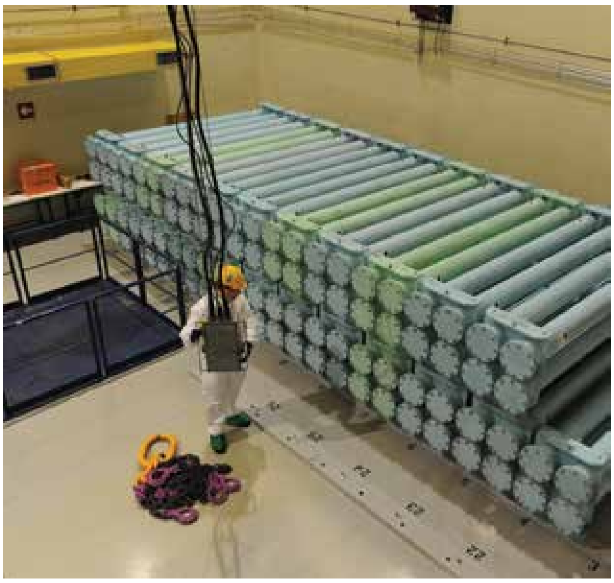
For enrichment, the current global commercial nameplate capacity of over 57 000 tSW is considered to be sufficient to cover demand at least until 2020. A key question concerns the extent to which China will increase its enrichment capacity and whether it will emerge as an exporter of enrichment services.

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 security of supply. In recent times, Russia has been winning many orders for new nuclear power plants worldwide, and aims to strengthen its position in the fuel market as well. On the other hand, an increasing number of VVER reactors might attract other competitors into this market segment.

## 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, there are some signs of possible new production. EU-based industry is active in 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 if there is a shortage. Currently, 10 % of the nuclear material used in fuel loaded into EU reactors comes from indigenous sources (see Table 5). These operations could be performed by EU industry.



([33]) *Uranium 2014: Resources, Production and Demand*, http://www.oecd-nea.org/ndd/pubs/2014/7209-uranium-2014.pdf.

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 based on demand, usually faster than it is to build new reactors, which gives a certain reassurance of supply security. 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.

Although 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.

Production capacity has recently been re-established for VVER-1000 fuel, produced in Sweden and used in Ukraine, and consideration is being given to re-establishing such capacity also for VVER-440 fuel manufacturing in the EU. In 2015, the Commission started funding a project called ESSANUF (European Supply of Safe Nuclear Fuel) which aims to facilitate the licensing of alternative VVER-440 fuel. Within the project consortium, entities from the Czech Republic, Finland, Slovakia, Spain, Ukraine and the United Kingdom are represented. The project's main objectives are to systematise knowledge concerning the behaviour of VVER-440 fuel during operation, improve the fuel design for new alternative VVER fuel, identify differences in licensing requirements between national authorities, and develop recommendations on possible standardisation.

## Demand side — assessment of the EU situation

Demand for nuclear materials and services in the EU is decreasing for the time being (see Chapter 3 for details). However, current estimates are based on firm current commitments and therefore do not include potential new NPPs which are being planned but not yet in construction.

For the moment, the EU is still the biggest regional nuclear fuel market in the world and remains an attractive business base for many intermediary companies, which in turn add liquidity to the market and contribute to the maintenance of physical stocks of uranium within EU-based facilities.

Natural uranium supplies to the EU are well diversified (see Figure 6 in Chapter 3). Furthermore, a number of key supplier countries are politically stable and have cooperation agreements with the EU. The situation does not raise shortage concerns 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. However, a prolonged closure of any of these facilities could create problems, including for EU customers.

The enrichment market is highly 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. The current challenge for the enrichment market is overcapacity and low prices.

For fuel fabrication, the situation is different since fuel assemblies are reactor specific and dependent on reactor design. While operators with western-design reactors usually have the choice between two or even three different fuel fabricators, four EU countries, namely Bulgaria, the Czech Republic, Hungary and Slovakia, operating exclusively VVER reactors are currently 100 % dependent on Russian suppliers of fuel assemblies. Additionally, two out of the four operating reactors in Finland are of the VVER-type, which represents 36 % of the country's nuclear electricity production. Striving to apply its policy on diversification of supply, in 2015 ESA once again urged operators of Russian VVER nuclear reactors in the EU, whose generation capacity accounts for 8.8 % of total EU capacity, to diversify their fuel suppliers. The dependence on one single supplier constitutes a risk, since qualifying an alternative supplier would take several years due to licensing and testing requirements. Some of the VVER operating utilities have started purchasing part of their EUP requirements from other market sources, which is a useful and welcome step towards full diversification.

The experience in Ukraine shows that there is an alternative fabricator for VVER-1000 reactors (Westinghouse, with fabrication based in Sweden). However, although Westinghouse-produced fuel was used at the Loviisa NPP in Finland in the past, it is not available at the moment. Following the conclusion of the ESSANUF project mentioned above, this option might again become available to the market in coming years.

While this project focuses on existing reactors, new VVER reactors being planned in the EU will be of a different type and it remains to be seen whether and when an alternative fuel fabricator will emerge for them. Therefore, it is essential that operators of the new reactors get sufficient information on the technical parameters of the fuel they need and are able to test alternative fuel options if another supplier is willing to develop them.

As a first step, utilities operating VVER reactors are encouraged to start diversifying the sourcing of nuclear materials and conversion and enrichment services, and some EU utilities are already moving in this direction.

### *Future contractual coverage rate*

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

### *Inventories*

Most EU utilities have inventories to cover 1 or 2 years of operation, in different forms (natural or enriched uranium, fabricated fuel assemblies). Some utilities are covered for more than 4 years, others only for a few months. In the current situation, the most vulnerable utilities in terms of security of supply remain those that depend on Russian fabricated fuel assemblies (VVER reactors), which cannot be quickly replaced by fuel assemblies from other manufacturers.

Compared to the previous year, the global level of inventories in the EU decreased slightly in 2015 as some utilities have been selling what may previously have been excessive inventories. This is understandable for utilities which will have to close down reactors in the coming years, but for other utilities it would be wise to consider increasing stocks at the currently relatively low prices.

Of course, the process of building up inventories of different chemical forms of nuclear material, and their appropriate level, should take into account the lead times for various steps of the fuel cycle. One possible guideline is that the inventory level should cover at least the lead time for a reload, i.e. 18 months of operation in the case of 18-month reloading campaigns.

### *Transport issues*

In assessing the supply security of nuclear fuel, one must carefully look at transport issues. Cross-border transport of radioactive materials has become increasingly complex and time-consuming due to the different approaches of national regulators. The main effects are interruption of and delays to consignments and, in extreme cases, shipment denials. This causes administrative burden and increases costs. The impacts of transport delays can be mitigated by diversifying fuel supply and developing different transport routes. Strategic inventories of materials and fuel would also help.

## ESA findings and recommendations

Following thorough analysis of the information gathered from EU utilities at the end of 2015 (as discussed in Chapter 3), ESA concluded 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 inventory levels should be maintained, not only by EU utilities but also by producers.

As regards fuel fabrication, there is concern about the 100 % reliance on one single supplier of VVER reactors in the EU. From a security-of-supply point of view, there should always be at least two alternative suppliers for each stage of the fuel cycle. The second best option is to have a diversified portfolio up to the fabrication stage and maintain a strategic stock of fabricated fuel. Ideally, all utilities should hold one or two reloads of fabricated fuel assemblies for each reactor, depending on the size of their reactor fleet and other electricity generation assets.

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, operators should establish contacts with potential fabricators interested in developing the required fuel.

Both operators and national regulators of countries operating VVER reactors could benefit from cooperation in the development, testing and licensing of alternative fuel.

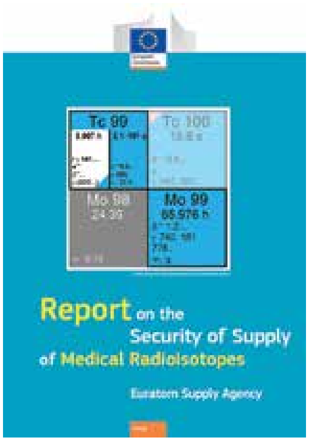
Although the above ESA recommendations are targeted mainly at utilities, it is clear that for long-term security of supply, EU producers should also maintain and further develop their technology and continue to invest in their production facilities to the extent possible under the prevailing market conditions.

# 5. Supply of medical radioisotopes

## *ESA involvement*

In the light of the Council Conclusions 'Towards the secure supply of radioisotopes for medical use in the EU' dated 2010 (34) and 2012 (35), ESA's observatory role was widened in 2013 to cover aspects of the supply of medical radioisotopes in the EU.

In 2015, ESA continued to coordinate 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 (36).




In addition to these activities, ESA prepared in 2015 a comprehensive report to the Commission on activities following up the Council Conclusions on medical radioisotopes. The report was adopted by the Commission in September 2015, and was presented in the Council's Working Group on Atomic Questions in October. The report (37) describes several initiatives which were undertaken to improve the security of supply of medical radioisotopes and which revolve around the European Observatory set up to help implement the policy adopted by the Council. It concluded that current production capacity remains fragile, as shown during the recent unplanned outages of research reactors and processing facilities. Therefore, the medical radioisotope issue still requires full consideration by EU institutions, Member States, regulators, industry and international organisations. The report discusses short- and medium-term actions to be undertaken to address this situation.

(34) http://ec.europa.eu/euratom/docs/118234.pdf
(35) http://ec.europa.eu/euratom/docs/2012_council_radioisotopes.pdf
(36) http://ec.europa.eu/euratom/observatory_radioisotopes.html
(37) http://ec.europa.eu/euratom/docs/ESA-MEP-web_final %20 14.09.2015.pdf

## *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, and the policies for their implementation. It is composed of representatives of the EU institutions and various industry stakeholders, most of which are grouped within the AIPES (Association of Imaging Producers and Equipment Suppliers) (38). The Observatory carries out its work in 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;

4 — Capacity and infrastructure development.

In 2015, the Observatory held two plenary meetings: in March in Luxembourg and in October in Hamburg. The latter was held at the Congress of the European Association of Nuclear Medicine (EANM), at which the Observatory had a booth at the expo and gave a presentation with the NEA at the EANM delegates assembly meeting.

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

Working Group 1 (WG1), with its core member AIPES, ensures effective coordination of reactor schedules to avoid and mitigate Mo-99 supply disruptions. The Emergency Response Team, created within WG1 and composed of representatives of research reactors, Mo-99 processors and Mo-99/Tc-99m generator manufacturers, follows production and supply issues week-by-week. This continuous follow-up makes it possible to identify potential Mo-99 shortages and to define mitigation action plans involving all stakeholders. In 2015, the ERT was activated to focus on the outage of the HFR reactor in The Netherlands, which lasted from mid-September to ear-

(38) http://www.aipes-eeig.org

ly December. During this period, detailed Mo-99 production monitoring was performed and all possible mitigation actions were undertaken. As a result, there were no significant supply shortages in 2015. In addition, a Joint Communication Team, set up in 2014 and aiming to promptly communicate with governmental representatives in case of supply interruptions, was activated during the HFR outage and provided information to stakeholders.

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

One of the key principles of the OECD/NEA HLG-MR [39] 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 infrastructure and to fully finance operating costs. Within the Observatory, the issue of FCR is handled by Working Group 2 (WG2). To facilitate EU discussion on this subject, a meeting on FCR was held in December 2015, gathering representatives of ESA, the Commission, AIPES, the OECD/NEA, Belgium, France and the Netherlands. The meeting concluded that FCR has to be achieved throughout the supply chain and that sufficient reimbursement should be made available to ensure sustainability of the Mo-99 supply. The true medical value of the radiopharmaceutical product would then be fully recognised. This topic was further addressed in a position paper tabled by the Dutch EU Presidency in 2016.

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

All countries currently producing radioisotopes have agreed to the principle of converting targets for Mo-99 production from HEU to LEU, implementing the work plan of the 2010 Washington Nuclear Security Summit.

Working Group 3 (WG3) carried out a study of the risks that could occur during the HEU-LEU conversion of targets used for radioisotope production. The study determined potential mitigating actions and gave recommendations for the radiopharmaceutical industry and policy-makers [40]. In the follow-up to these recommendations, WG3 liaised with the European Medicines Agency (EMA) [41] on the subject of drug regulatory agencies authorising a new LEU-based Mo-99. In 2015, representatives of AIPES and of radiopharmaceuticals manufacturers met with the Coordination Group for Mutual Recognition and Decentralised Procedures — human (CMDh) [42] at EMA's premises to discuss regulatory issues on the approval of non-HEU based Mo-99/Tc-99m. Further to the WG3 recommendations, the Observatory agreed to contact the European Association of Competent Authorities for the Safe Transport of Radioactive Material (EACA) [43] to discuss the issue of regulatory approval of containers and transportation licences for uranium targets in EU Member States.

Furthermore, at the request of WG3, the processors based in the EU regularly update the Observatory with their schedules of conversion to non-HEU processes. Such information is instrumental to monitoring overall progress on HEU-LEU conversion and to defining European needs for HEU/LEU material.

The importance of converting irradiation targets from HEU to LEU was highlighted in the Council Conclusions adopted in 2012, which called upon the Commission to propose to Member States a relevant instrument to provide Community support for the conversion and to identify the needs of research that might be supported by the Euratom research and training programme [44].

In response to the Council, the Commission proposed, under 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 (NFRP-08-2015). As a result, a research and innovation action grant of EUR 6.4 million was awarded to the HERACLES-CP project [45], which kicked-off in December 2015. This project, aimed 'towards the conversion of high performance research reactors in Europe', is coordinated by the Technische Universität München (TUM) and involves five partners, three of which are or will be producers of medical radioisotopes.

It should be noted that the conversion of research reactors (especially high-performance reactors) is technically very challenging and requires ongoing work, whereas the conversion of uranium targets is on its way to being complete.

Stakeholders discussed this subject at Observatory meetings, and considered it vital to ensure the availability of HEU during the transition period until the conversion process is completed. This is to ensure the uninterrupted production of medical radioisotopes. Another closely related aspect is the supply of uranium (both HEU and LEU) for the fabrication of fuel for the European research reactors in which medical radioisotopes are produced.

It remains very important to scrutinise the potential risks to the security of supply of HEU and LEU, and to strive to obtain sufficient supplies of them, as neither HEU nor LEU (enriched to 19.75 %) is currently produced in the EU (the USA and the Russian Federation are the only suppliers).

(39) The NEA established the HLG-MR in 2009 to examine the underlying reasons for the global 2009-2010 supply shortage and to develop a policy approach to ensure the long-term security of supply of Mo-99/Tc-99m.
(40) http://ec.europa.eu/euratom/docs/WG3 %20report.pdf
(41) http://www.ema.europa.eu/ema
(42) http://www.hma.eu/cmdh.html
(43) http://www.euraca.eu/
(44) http://ec.europa.eu/euratom/docs/2012_council_radioisotopes.pdf
(45) http://www.heracles-consortium.eu/

To this end, in close cooperation with the Member States concerned, in 2015 ESA continued striving to secure the supply of HEU for those users that still need it, in compliance with international nuclear security commitments. It organised two meetings in 2015 to discuss the implementation of the Memorandum of Understanding signed with the US DOE-NNSA in 2014, focusing on the proposed list of excess materials that EU holders consider for the exchange.

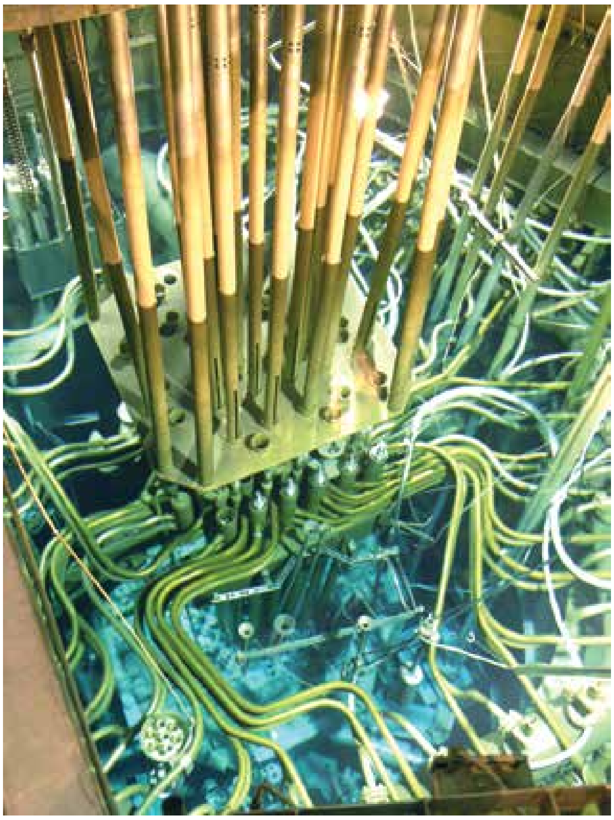
### *Working Group 4 — Capacity and infrastructure development*

The main objective of Working Group 4 (WG4) is to examine Mo-99 production capacity and infrastructure developments for both reactors and processing facilities.

In line with its revised mandate, in 2015 the WG4 continued to monitor the radioisotope market. The analyses oscillated mainly around the forecast of radioisotope demand and current and future Mo-99/Tc-99m production capacity in the EU. Some preliminary results of Mo-99/Tc-99m demand analysis based on European projects Dose Data Med (DDM) and Dose Data Med 2 (DDM2) ([46]) were presented to the Observatory. WG4 suggested that surveying the prices and reimbursement schemes for radiopharmaceuticals in the EU should also be part of the Observatory's scope. In line with this, further contacts with the EANM were established, so as to benefit from its knowledge of the European medical radioisotope market, especially in light of the recent EANM survey carried out among its national delegates.

### *Outlook*

It is worth noting that the coming years will be challenging, as they include periods of increased risk of Mo-99 shortages, in view of the extended shutdown of the BR2 reactor in Belgium



for the replacement of its beryllium matrix (February 2015 to June 2016), the definitive shutdown of the OSIRIS reactor in France (December 2015), the decision to cease routine Mo-99 production in the NRU reactor in Canada (November 2016) and the transition period (2016-2017) to allow for the conversion of targets for radioisotope production from HEU to LEU.

Stakeholders should also pay particular attention to the need to ensure the operational sustainability of the sole European supplier of research reactor fuel and uranium targets (CERCA), which is now implementing an extensive programme of safety upgrades with major investment needed.

([46]) http://ddmed.eu/

# 6. ESA's Work Programme for 2016

In line with ESA's remit, as per Chapter 6 of the Euratom Treaty and its statutes, ESA's work programme for 2016 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**

Diversification of sources of supply with a view to preventing excessive dependence on any single external supplier is of paramount importance for the medium- and long-term security of nuclear fuel supply to EU utilities. Taking due account of the Commission Communication of 28 May 2014 on the European Energy Security Strategy (47), ESA will continue to work towards ensuring the security of supply, by evaluating supply contracts submitted to it for conclusion and acknowledging transactions duly notified to it and covering the provision of services in the entire nuclear fuel cycle. It will keep focusing on the supply of HEU for non-converted research reactors and targets and, increasingly, on the future supplies of LEU required for producing medical radioisotopes and fuelling research reactors.

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

ESA will continue to seek advice from its Advisory Committee on the further development of its Nuclear Market Observatory, including assessments of information tools it created. It will continue to support the activities of the Advisory Committee's working groups.

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

With a view to efficiently carrying out the Nuclear Market Observatory's tasks and contributing to security of supply, ESA will actively pursue its relations with international bodies. As in the previous year, ESA will implement the Memorandum of Understanding signed in December 2014 with the US Department of Energy/National Nuclear Security Administration (US DoE/NNSA), coordinating with the Member States concerned where necessary.

(47) COM(2014) 330, final.

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

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

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

Aiming to further improve the management of the contracts it receives and the operations of its Nuclear Market Observatory, ESA will continue to review its procedures. In this context, it will continue its work on revising and having approved, under the Euratom Treaty and the applicable secondary law, its rules determining the way 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, ESA'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 has been, and remains, a key priority of the EU energy policy.

ESA monitors the diversification of sources by evaluating contracts which were submitted to it for conclusion and which pertain to the supply of ores, source materials and special fissile materials coming from within or outside the EU (Article 52 of the Euratom Treaty). Notifying ESA of contracts relating to the processing, conversion or shaping of materials (Article 75 of the Treaty), as well as of transactions involving the transfer, import or export of small quantities of materials (Article 74), contribute to keeping it up-to-date on the needs and the industrial capacity of EU companies.

Supply contracts concluded before a Member State's EU accession, under Article 105 of the Euratom Treaty, are exempted from the diversification requirement until they expire or are modified. New supply contracts for the same 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 required to produce medical radioisotopes (Mo-99/Tc-99m) and to fuel research reactors. Neither such HEU nor 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, under Article 52 of the Euratom Treaty, in conformity with the EU supply/diversification policy, and within the statutory deadline.

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

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

4. Keep monitoring the need for HEU and LEU required to produce medical radioisotopes and to fuel research reactors; strive to ensure the supply of these materials, including through negotiations with supplier countries.

5. On request, support the Commission's nuclear materials accountancy staff in verifying contract data contained in prior notifications on the movements of nuclear materials.

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

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

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

Acting as the secretariat of the Advisory Committee's working group on 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. As in the previous year, it will provide support to the working group on intermediaries.

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

These activities lay the foundations for building up comprehensive overviews of the current state and emerging trends of the nuclear fuel cycle market. ESA's Annual Report, *Quarterly Uranium Market Report* and weekly *Nuclear News Digest*, circulated within the Commission, will remain the main ways in which the Nuclear Market Observatory's analyses are presented. The Observatory will continue to regularly update ESA's website, which offers information on market developments.

ESA's Nuclear Market Observatory will continue to cooperate with the Energy Observatory of the Commission's Directorate-General for Energy.

In line with the Nuclear Market Observatory's mission to cover aspects of the supply of medical radioisotopes in the EU, ESA will continue to chair the European Observatory on the Supply of Medical Radioisotopes and to coordinate actions undertaken by various services to improve the security of supply of Mo-99/Tc-99m, the most vital medical radioisotope.

**Specific objective No 2**

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

1. continue to support the activities of the Advisory Committee's working group on security of supply scenarios;

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

3. publish its Annual Report, including market analyses, by July 2016;

4. continue to publish annual natural uranium price indices (long-term, medium-term, spot and quarterly);

5. chair and lead the activities of the European Observatory on the Supply of Medical Radioisotopes;

6. regularly update the medical radioisotope section on ESA's website;

7. provide support to the activities of the Advisory Committee's working group on intermediaries.

## *Cooperating with international organisations and third countries*

Groups of international experts are increasingly seeking out ESA's analyses of the nuclear fuel cycle market due to their quality and neutrality. In order to raise the profile of its activities as a Nuclear 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 other international players on the nuclear fuel market. It will continue its membership in the WNA and the World Nuclear Fuel Market (WNFM).

With a view to ensuring regular HEU supplies for as long as necessary, ESA will pursue more cooperation with the US DoE/NNSA. The next important actions in this context are the drawing up of a list of materials eligible for exchange under the Memorandum of Understanding and the release of a Joint Statement at the margins of the 2016 Nuclear Security Summit in Washington. These actions are necessary steps towards ensuring continuity in the functioning of EU research reactors.

**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 on nuclear energy matters (as soon as this becomes politically feasible).

4. Maintain contacts with the USA, notably for the sake of securing the supply of HEU and LEU required for the production of medical radioisotopes; follow up on the 2014 Memorandum of Understanding with this context in mind.

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

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

The results of the following ongoing projects may be of interest for ESA:

- HERACLES-CP, which is a HORIZON 2020 project supported by the Commission's DG RTD, and a central pillar of the programme for the development and qualification of high-density LEU fuel to be used in research reactors and processes presently fuelled with HEU after their conversion.
- ESSANUF, i.e. the 'European Supply of Safe Nuclear Fuel' project, which aims at the qualification of nuclear fuel produced by alternative suppliers for VVER-designed power reactors operating in the EU.

**Specific objective No 4**

1. Continuously monitor technological developments relating to the nuclear fuel cycle management, with a view to adapting ESA'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 restricted resources.

**Specific objective No 5**

1. Revise and have approved the ESA's rules determining the way in which demand is to be balanced against the supply of ores, source materials and special fissile materials (under Article 60(6) of the Euratom Treaty and Article 13(3) of ESA's statutes).

2. Continue to review ESA's work practices and internal control standards and update them to the extent appropriate; continue to update the manual of procedures for the 'contract management' and Nuclear Market Observatory sectors.

3. Continue to ensure sound financial and budgetary management.

4. Review/update the Memorandum of Understanding with the Commission's Directorate-General for Energy.

# Contact information

## ESA address for correspondence

Euratom Supply Agency
European Commission

EUFO 1
Rue Alcide de Gasperi
2920 Luxembourg
LUXEMBOURG

## Office address

Complexe Euroforum
10, rue Robert Stumper
2557 Luxembourg
LUXEMBOURG

Tel. +352 430137147
Fax +352 430138139

## Email

Esa-AAE@ec.europa.eu

## Website

This report and its 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, from the above address.

## Further information

Additional information can be found on the EUROPA website:
http://europa.eu/index_en.htm.

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

More information on the Commission's Directorate-General for Energy can be found at:
http://ec.europa.eu/energy/index_en.html.

This website contains information on areas such as security of energy supply, energy-related research, nuclear safety, and liberalisation of the electricity and gas markets.

# 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.

# Annexes

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

*(A) 2016-2025*

| Year | Natural uranium | | Separative work | |
|---|---|---|---|---|
| | Gross requirements | Net requirements | Gross requirements | Net requirements |
| 2016 | 17 037 | 13 963 | 13 740 | 11 542 |
| 2017 | 17 976 | 14 791 | 14 460 | 12 733 |
| 2018 | 16 602 | 14 372 | 13 615 | 12 264 |
| 2019 | 18 314 | 16 472 | 15 003 | 13 857 |
| 2020 | 16 823 | 14 702 | 13 605 | 12 795 |
| 2021 | 16 650 | 14 847 | 13 556 | 12 759 |
| 2022 | 16 203 | 14 670 | 13 473 | 12 675 |
| 2023 | 16 370 | 14 782 | 13 469 | 12 561 |
| 2024 | 15 598 | 13 720 | 12 758 | 11 645 |
| 2025 | 15 876 | 14 419 | 12 895 | 12 085 |
| **Total** | **167 447** | **146 739** | **136 573** | **124 917** |
| **Average** | **16 745** | **14 674** | **13 657** | **12 492** |

*(B) Extended forecast 2026-2035*

| Year | Natural uranium | | Separative work | |
|---|---|---|---|---|
| | Gross requirements | Net requirements | Gross requirements | Net requirements |
| 2026 | 15 026 | 13 512 | 12 200 | 11 352 |
| 2027 | 15 042 | 13 432 | 12 232 | 11 312 |
| 2028 | 15 277 | 13 663 | 12 404 | 11 482 |
| 2029 | 14 371 | 12 868 | 11 719 | 10 881 |
| 2030 | 14 509 | 13 099 | 11 848 | 11 078 |
| 2031 | 14 614 | 13 204 | 11 921 | 11 151 |
| 2032 | 14 284 | 12 797 | 11 656 | 10 822 |
| 2033 | 14 262 | 12 776 | 11 662 | 10 828 |
| 2034 | 14 416 | 13 006 | 11 767 | 10 997 |
| 2035 | 14 079 | 12 669 | 11 495 | 10 725 |
| **Total** | **145 879** | **131 026** | **118 905** | **110 629** |
| **Average** | **14 588** | **13 103** | **11 890** | **11 063** |

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

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

(*) Data not available.

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

## Annex 3
## ESA average prices for natural uranium

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

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

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

## Annex 4
## Purchases of natural uranium by EU utilities, by origin, 2006-2014 (tU)

| Country | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|
| Russia | 3 984 | 5 144 | 3 272 | 3 599 | 4 979 | 4 524 | 5 102 | 3 084 | 2 649 | 4 097 |
| Kazakhstan | 527 | 557 | 1 072 | 1 596 | 2 816 | 2 659 | 2 254 | 3 612 | 3 941 | 2 949 |
| Canada | 5 093 | 3 786 | 4 757 | 3 286 | 2 012 | 3 318 | 3 212 | 3 156 | 1 855 | 2 845 |
| Niger | 3 355 | 3 531 | 1 845 | 1 854 | 2 082 | 1 726 | 2 376 | 2 235 | 2 171 | 2 077 |
| Australia | 3 053 | 3 209 | 2 992 | 3 801 | 2 153 | 1 777 | 2 280 | 2 011 | 1 994 | 1 910 |
| Uzbekistan | 530 | 938 | 1 070 | 589 | 459 | 929 | 159 | 653 | 365 | 526 |
| EU | 472 | 526 | 515 | 480 | 556 | 455 | 421 | 421 | 397 | 412 |
| Namibia | 790 | 865 | 696 | 435 | 1 017 | 1 011 | 1 350 | 716 | 325 | 385 |
| United States | 488 | 402 | 398 | 318 | 320 | 180 | 241 | 381 | 586 | 343 |
| Other | 1 336 | 432 | 520 | 329 | 432 | 128 | 256 | 621 | 299 | 229 |
| Re-enriched tails | 728 | 388 | 688 | 193 | 0 | 0 | 0 | 0 | 0 | 212 |
| Malawi | 0 | 0 | 0 | 0 | 0 | 0 | 180 | 115 | 125 | 2 |
| South Africa | 188 | 137 | 247 | 426 | 190 | 113 | 412 | 17 | 20 | 1 |
| HEU feed | 850 | 825 | 550 | 675 | 550 | 731 | 395 | 0 | 0 | 0 |
| Ukraine | 0 | 123 |  | 10 | 0 | 284 | 0 | 0 | 23 | 0 |
| **Total** | **21 394** | **20 864** | **18 622** | **17 591** | **17 566** | **17 832** | **18 639** | **17 023** | **14 751** | **15 990** |

## Annex 5
## Use of plutonium in MOX in the EU-28 and estimated natural uranium and separative work savings

| Year | kg Pu | Savings | |
|---|---|---|---|
| | | tNatU | tSW |
| 1996 | 4 050 | 490 | 320 |
| 1997 | 5 770 | 690 | 460 |
| 1998 | 9 210 | 1 110 | 740 |
| 1999 | 7 230 | 870 | 580 |
| 2000 | 9 130 | 1 100 | 730 |
| 2001 | 9 070 | 1 090 | 725 |
| 2002 | 9 890 | 1 190 | 790 |
| 2003 | 12 120 | 1 450 | 970 |
| 2004 | 10 730 | 1 290 | 860 |
| 2005 | 8 390 | 1 010 | 670 |
| 2006 | 10 210 | 1 225 | 815 |
| 2007 | 8 624 | 1 035 | 690 |
| 2008 | 16 430 | 1 972 | 1 314 |
| 2009 | 10 282 | 1 234 | 823 |
| 2010 | 10 636 | 1 276 | 851 |
| 2011 | 9 410 | 824 | 571 |
| 2012 | 10 334 | 897 | 622 |
| 2013 | 11 120 | 1 047 | 740 |
| 2014 | 11 603 | 1 156 | 825 |
| **2015** | **10 780** | **1 050** | **742** |
| **Grand total** | **195 019** | **22 006** | **14 838** |

## Annex 6
## EU nuclear utilities that contributed to this report

| |
|---|
| ČEZ, a.s. |
| EDF and EDF Energy |
| EnBW Kernkraft GmbH |
| ENUSA Industrias Avanzadas, S.A. |
| E.ON Kernkraft GmbH |
| EPZ |
| Fortum Power and Heat Oy |
| Ignalina NPP |
| Kozloduy NPP Plc |
| Nuklearna elektrarna Krško, d.o.o. |
| Magnox Ltd (UAM) |
| 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. USA |
| CNU |
| Cominak |
| DIAMO |
| Internexco GmbH |
| Itochuint |
| KazAtomProm |
| Macquarie Bank Limited, London Branch |
| NUKEM GmbH |
| Paladin Energy Ltd |
| Rio Tinto Marketing Pte Ltd |
| Tenex (JSC Techsnabexport) |
| Traxys North America LLC |
| TVEL |
| UEM |
| UG — Urangesellschaft MbH |
| Uranium One |
| Urenco Ltd |
| USEC — United States Enrichment Corporation |

# Annex 8
# Calculation method for ESA's average $U_3O_8$ prices

## *ESA price definitions*

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

In order to enhance market transparency, ESA calculates three uranium price indices on an annual basis:

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

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

3. The ESA 'MAC-3' multiannual $U_3O_8$ price is a weighted average of $U_3O_8$ prices paid by EU utilities, but only under multiannual contracts which were concluded or for which the pricing method was amended in the previous 3 years (i.e. between 1 January 2013 and 31 December 2015) and under which deliveries were made during the reference year. In this context, ESA regards amendments which have a direct impact on the prices paid as separate contracts.

In order to ensure statistical reliability (sufficient amounts) and safeguard the confidentiality of commercial data (i.e. ensure that details of individual contracts are not revealed), ESA price indices are calculated only if there are at least five relevant contracts.

As from 2011, ESA introduced its quarterly spot $U_3O_8$ price, an indicator published on a quarterly basis if EU utilities have concluded at least three new spot contracts.

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

## *Definition of spot vs long-term/multiannual contracts*

The difference between spot and multiannual contracts is as follows:

- spot contracts provide either for one delivery only or for deliveries over a maximum of 12 months, whatever the time between conclusion of the contract and the first delivery;

- multiannual contracts provide for deliveries extending over more than 12 months.

The average spot-price index reflects the latest developments on the uranium market, whereas the average price index of uranium delivered under multiannual contracts reflects the average long-term price paid by European utilities.

## *Method*

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

## *Data collection tools*

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

- contracts submitted to ESA;

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

## *Data requested on natural uranium deliveries during the year*

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

## *Deliveries taken into account*

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

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

## *Data quality assessment*

ESA compares the deliveries and prices reported with the data collected at the time of conclusion of the contracts, taking into account any subsequent updates. In particular, it compares the actual deliveries with the ‘maximum permitted deliveries’ and options. Where there are discrepancies between maximum and actual deliveries, clarifications are sought from the organisations concerned.

### *Exchange rates*

To calculate the average prices, the original contract prices are converted into euros per kgU contained in $U_3O_8$ using the average annual exchange rates published by the European Central Bank.

### *Prices which include conversion*

For the few prices which include conversion but where the conversion price is not specified, given the relatively minor cost of conversion, ESA converts the $UF_6$ price into a $U_3O_8$ price using an average conversion value based on reported conversion prices under the natural uranium long-term contracts.

### *Independent verification*

Two members of ESA’s staff independently verify spreadsheets from the database.

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

### *Data protection*

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

## Annex 9
## Declaration of assurance

*I, the undersigned, Stamatios Tsalas*

*Director-General of Euratom Supply Agency in 2015*

*In my capacity as authorising officer*

*Declare that the information contained in this report gives a true and fair view ([48]).*

*State that I have reasonable assurance that the resources assigned to the activities described in this report have been used for their intended purpose and in accordance with the principles of sound financial management, and that the control procedures put in place give the necessary guarantees concerning the legality and regularity of the underlying transactions.*

*This reasonable assurance is based on my own judgement and on the information at my disposal, such as the results and the lessons learnt from the reports of the Court of Auditors for years prior to the year of this declaration.*

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

*Luxembourg, March 2016*

*Stamatios Tsalas*

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

**Photo credits**

Page 9: Aerial view Saint-Paul-lez-Durance © ITER Organisation
Page 11: Jules Horowitz Reactor (in construction) © CEA — G Lesénéchal/CEA, September 2015
Page 19: Somaïr open pit © AREVA — Ascani Maurice
Page 22: Uranium oxide pellets © ENUSA
Active scanner for inspection of fuel rods of uranium oxide © ENUSA
Page 24: Nuclear reactor core © 3dalia/iStock/Thinktock
Mochovce NPP — Fresh fuel © Slovenské Elektrárne
Page 28: Uranium concentrate in drum © ČEZ
Page 33: An open autoclave © URENCO
Page 38: Loviisa fresh fuel storage showing transport packages of VVER-440 fuel © Fortum
Page 43: Maria Research Reactor, Poland © NCBJ Otwock Poland
Page 46: Grohnde nuclear power plant © EON

MJ-AA-16-001-EN-N

Publications Office

ISBN 978-92-79-58373-5