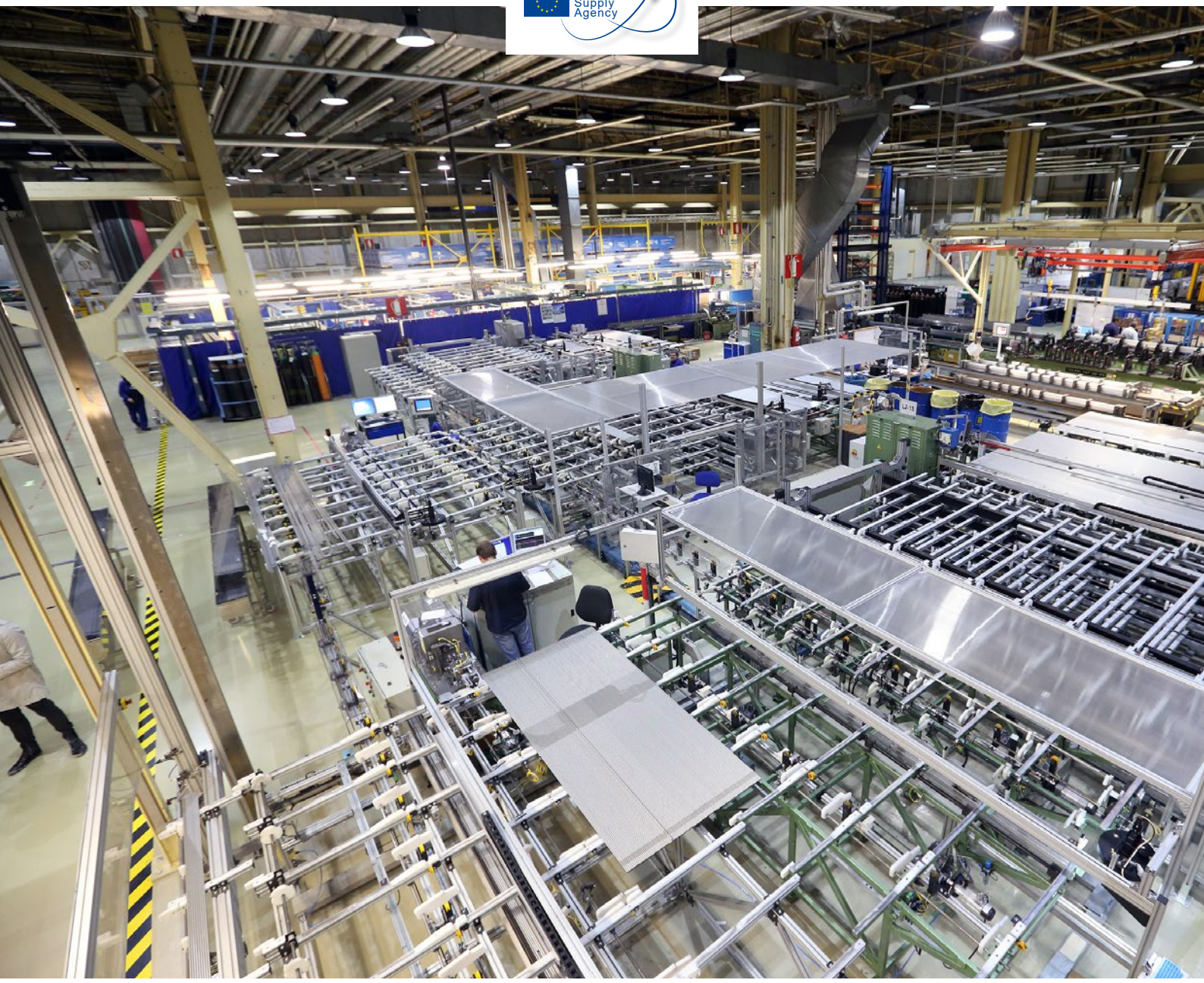

Analysis of Nuclear Fuel Availability at EU Level from a Security of Supply Perspective

REPORT

Euratom Supply Agency Advisory Committee
Working Group on Prices and Security of Supply

March 2020

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1. Executive summary

Nuclear energy remains a key source of low-carbon electricity generation in the European Union. This report identifies threats and restrictions which could potentially jeopardise the availability of nuclear fuel and the provision of electricity at affordable prices to all EU consumers. In order to provide a more accurate analysis of the different risks, this report offers a new methodology for evaluating risk that takes into account the duration of impact on supply.

The most common way for utilities to secure their supply of nuclear fuel is to have a diversified portfolio of suppliers at every step of the nuclear fuel cycle (natural uranium, conversion, enrichment and fabrication). However, situations of overcapacity in both the natural uranium market and the conversion market and low prices have led to the temporary closure of some of these facilities in order to bring production down to the level of demand.

Following along the fuel chain, the uranium market's top risks are a:

- 'permanent reduction of production and withdrawal from uranium exploration' (risk 3),
- 'lack of investment in new mines' (risk 6) and
- 'temporary suspension of production or shortage in uranium mines' (risk 7).
- In the conversion market,
- 'lack of investments in conversion facilities' (risk 2), and_
- 'temporary suspension of production, or shortage of capacity of conversion' (risk 5).

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Langer Heinrich shipping drums

These risks could lead to a mismatch between demand and supply, particularly in terms of quantities, but also in terms of required regional diversification and/or producer diversity in the utilities' supply portfolios. This makes diversification more difficult to maintain, puts pressure on prices and may result in a shortage of nuclear material.

Therefore utilities should maintain an appropriate level of strategic inventory of nuclear fuel material; the appropriateness of supplier country, volume, form and location has to be reviewed regularly to ensure there is a sufficiently diversified fuel supply. Early warnings by EU institutions and concerted industry action would also be helpful.

Transportation of nuclear material is required at every step and has become a major concern. On the one hand, several European ports have followed local political decisions not to accept any new shipments of nuclear material, and some shipping companies have also become more reluctant to transport nuclear material. In order to prevent a

- 'lack of transport hubs open to nuclear shipments' (risk 1), alternative routes as well as the usage of dedicated charter vessels should be put into place promptly. It is also important to make different stakeholders aware of the excellent safety record of the transport of radioactive materials. On the other hand, the
- 'lack of harmonisation and multiple regulation in transport authorisation' (risk 4) remains problematic. Efforts should continue to develop a harmonised pan-European arrangement for handling cross-border transport package approvals, which would be valid in each country.

Strategic inventories are also a way for utilities to prevent any disruption of supply due to political reasons. Both issues of

- 'Security of supply in light of the current political situation e.g. access restrictions to nuclear material and related services' (risk 8) and
- 'supply disruption resulting from political instability' (risk 9)

must also be mitigated by implementing geopolitical monitoring.

The report also identifies a risk of overdependence on a single source of supply, namely

- 'Overdependence on a single source of supply of fuel fabrication services' (risk 10).

Overdependence on a single source of supply of fuel fabrication services was selected as the most important (highest risk) of the four risks identified and related to overdependence on a single source of supply at any stage of fuel cycle (natural uranium, conversion, enrichment and fuel fabrication). The mitigation of diversification of supply remains common to those four risks as well as to many others.

The table below describes actors and recommended actions to address particular risks. It explains which stakeholder on the nuclear fuel market has influence to mitigate the risk by undertaking appropriate actions.

Actor	Recommendations
UTILITY	- Perform risk analysis - Diversify - Monitor the geopolitical situation - Maintain an appropriate inventory, specified in level and in form resulting from risk analysis and on-going monitoring - Ensure advance delivery of fabricated fuel - Ensure qualification of alternative fuel designs, fabrication plants or vendors - Maintain long-term and flexible contracts - Share risks and benefits with converters under e.g. long-term conversion contracts - Exchange information between utilities on fuel design operating experience
SUPPLIER	- Continuously endeavour to prove its reliability and improve transparency - Be more open to support the on-going monitoring of market risks - Ensure proactive licensing by fuel vendors in potential market areas
REGULATOR	- Harmonise regulations - Monitor whether vendors and utilities are abusing their dominant position if applicable - Apply appropriate antitrust measures
MEMBER STATE	- Secure a fair electricity market and fair conditions for all sources of electricity generation - Consider and treat nuclear generation as a strategic sector of energy supply - Accept a pan-European arrangement for package approvals for cross-border transport
EU/ESA	- Ensure ongoing monitoring of the market and early warnings - Perform risk analysis - Consider, treat and promote nuclear generation as a strategic sector of energy supply - Monitor any appearance of possible supply risks and their probability and recommend mitigation measures - Create a pan-European arrangement for handling cross-border transport package approvals and mutual recognition of registered carriers

2. ESA objectives and resources

A common nuclear market in the EU was created by the Euratom Treaty. Article 52 of the Treaty established the Euratom Supply Agency (ESA) to ensure a regular and equitable supply of nuclear fuels to EU users in line with the objectives of Article 2(d). To perform this task, ESA applies a supply policy based on the principle of equal access of all users to ores and nuclear fuel. In carrying out the tasks entrusted to it by the Euratom Treaty, ESA processes every year more than 300 transactions, including contracts, amendments and notifications of front-end activities. Under the Euratom Treaty, ESA is endowed with a right of option on ores, source materials and special fissile materials produced in the territories of Member States and has an exclusive right to conclude contracts for the supply of ores, source materials and special fissile materials coming from inside the Community or from outside.

To increase market transparency, ESA conducts an annual market survey and gives its detailed analysis of the EU nuclear fuel market as well as its vision of the global nuclear fuel market. It identifies market trends that could affect the security of the European Union's supply of nuclear materials and services and provides EU stakeholders with expertise and advice.

ESA, together with its Advisory Committee, forms a unique mix of precise knowledge of the EU nuclear market and experience. It is required to use these assets for drawing up proposals, recommendations and decisions influencing the nuclear market not only when possible supply problems may occur but far in advance, before any difficulties could harm the European market.

The expertise of ESA offering early warning should be used together with concentrated industry action. The ESA annual survey is of the utmost importance in monitoring the EU market.

In order to accomplish its mission and maintain its position in a changing environment, ESA has at its disposal staff with a high level of expertise in administering contracts submitted by the European nuclear operators for ESA's agreement, and collecting and analysing data from the industry.

In order to maintain its role in evaluating the market, advising and making recommendations, ESA sustains a balanced cooperation with other international bodies and organisations e.g. the IAEA, OECD-NEA, WNA and WNFM. ESA continues to contribute to international reports, reviews and specialised publications, enhancing its international recognition and visibility.

3. General context of the work

European energy security is a priority in the EU. It is a pillar of the European energy security strategy adopted by the European Commission on 28 May 2014, and also one of the five pillars of the EU energy union, created by the Commission on 25 February 2015.

The Commission's energy security strategy was a response to the dependence of many Member States on one supplier of energy sources. This dependence, whether on gas, oil or nuclear, leaves these countries vulnerable to supply disruptions, whether caused by political or commercial disputes, or infrastructure failure.

A European internal market for energy is seen as a key factor in energy security and is the delivery mechanism for achieving it in a cost-effective way. Government interventions that affect this market framework, such as national decisions on renewable energy or efficiency targets, decisions to support investment in nuclear generation, or decisions to support key infrastructure projects need to be discussed at European and/or regional level to ensure that decisions in one Member State do not undermine security of supply in another Member State. Various tools exist at EU level to implement such projects in a coordinated manner. A real European energy security strategy requires that enforcement tools be preceded by a strategic discussion at EU level, not just at national level.

The energy union aims to give consumers secure, sustainable, competitive and affordable energy. It does so by overhauling European energy and climate systems and policies, putting the EU at the forefront in addressing global renewable energy and climate change.

According to the Fourth Report on the State of the Energy Union, it will be essential in the coming years to integrate and innovate in all economic sectors a wide range of related policies and various scales of action. This approach — including energy, climate mitigation and adaptation, air quality, digital technologies, industry, transport, land, agriculture, social issues, security, and many other issues — needs to be developed at European, national, regional, and local level. It will equip the EU with the capacity to deal with future challenges, such as digitisation, consumer empowerment, and the development of flexible electricity markets that can cope with high shares of variable renewables.

The EU has considerably raised its ambition by setting new targets in energy policy for 2030, namely: to reduce greenhouse gas emissions domestically by at least 40% compared to 1990 levels; to reach a share of at least 32% in renewable energy; and to increase energy efficiency by at least 32.5%. The electricity interconnections target was set to improve security of supply by stepping up to 15% of installed electricity production in each Member State by 2030.

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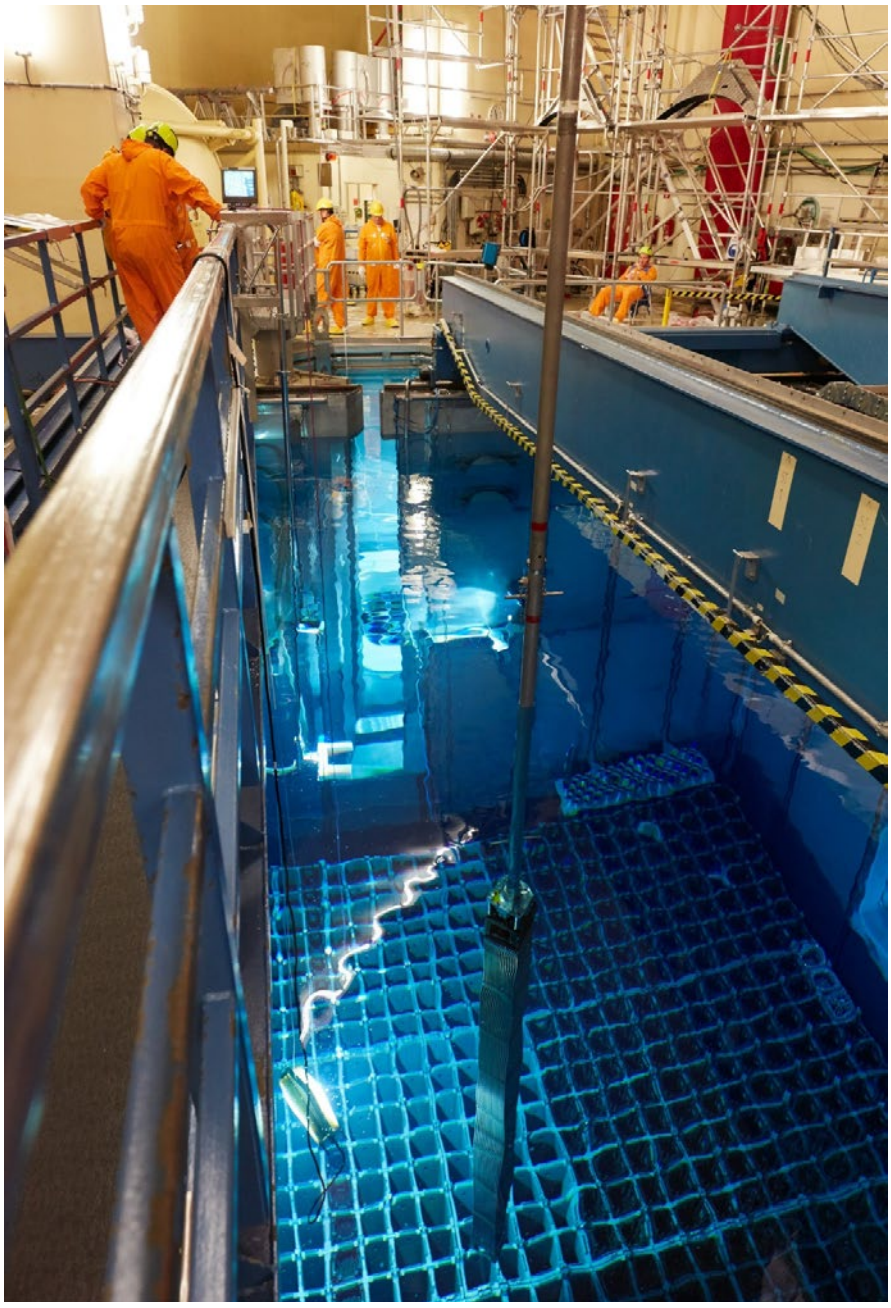
The EU's strategic long-term vision for a prosperous, modern, competitive and climate neutral economy by 2050 will be essential to give a clear direction to the further development of the energy union. The proposal put forward by the European Commission on 28 November 2018 points the way to a climate-neutral and modern economy. It underlines once again the importance of the EU's wide-ranging enabling framework to attain climate neutral status by mid-century. This framework promotes favourable conditions on finance and investment through the internalising of externalities, a consistent research and innovation agenda, a just transition for regions, economic sectors and the general public, and a full use of relevant policies, including the EU's budget, employment and cohesion policies.

On 24 December 2018 the Regulation on the governance of the energy union and climate action entered into force. In accordance with the Regulation, by the end of December 2019 EU countries are to have developed integrated national energy and climate plans (NECPs) that cover the five dimensions of the energy union from 2021 to 2030 (and every subsequent 10-year period). Each Member State must then report on the progress it makes in implementing its NECP.



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Reactor pool

The Commission will monitor the EU's progress as a whole, notably as part of the annual state of the energy union report. The new rules underline the importance of effective public participation and regional cooperation in developing and implementing these plans, ensuring that the views of individuals and businesses as well as regional and local authorities are heard.

The EU needs to maintain its nuclear expertise and technical capacity so that it can contribute to these goals with a stable and reliable supply of nuclear fuel to the EU's nuclear power plants. By 2050, nuclear power, with its anticipated share in the EU energy mix of approximately 15%, will be, together with renewable energy sources, the backbone of a carbon-free European power system.

Electricity produced from nuclear power plants constitutes a reliable base load of low carbon supply and plays a strategic role in energy security. The relative value of nuclear fuel is marginal in relation to the total production cost of electricity compared to gas or coal-fired plants. The worldwide uranium supply market is stable and well diversified, but the EU is nonetheless completely dependent on external supplies. There are only a few entities in the world involved in the nuclear fuel cycle, but the EU industry has technological leadership on the whole chain, including conversion, enrichment, fabrication, reprocessing and recycling.

The supply and demand situation for nuclear fuels in the EU could change radically by 2030. Given the nuclear phase-out strategy adopted in Germany and Belgium, and the energy transition announced by the French government, the five on-going new build reactor projects in three Member States and a couple of new projects which will be commissioned in the near future will not be able to compensate for all possible shutdowns.

Facts and figures on the EU nuclear industry

- There are 126 commercial nuclear operating power reactors in the EU spread across 14 Member States; 5 units are under construction.
- EU nuclear gross electricity generation accounts for 25.2% of total EU-28 production.
- Demand for uranium in the EU constitutes about 25% of world uranium demand.
- 100 % of natural uranium delivered to the EU on an annual basis comes from diversified sources outside Europe; nevertheless, the EU has substantial resources of uranium whose exploitation cannot be economically justified in the prevailing conditions.
- 8-10% of the fuel loaded into EU reactors comes from sources, such as the use of MOX fuel together with reprocessed uranium.
- Deliveries of conversion services to EU utilities are well diversified, more than 40% coming from domestic sources.
- Deliveries of enrichment services are well diversified, more than 60% coming from domestic sources.
- EU industry has technological leadership on the whole fuel supply chain, including mining, conversion, enrichment, fuel fabrication and reprocessing, reactor design and operating.
- The newly built Philippe COSTE conversion plant and the Georges BESSE 2 enrichment plant in France, 3 other enrichment facilities in Germany, the Netherlands, the United Kingdom, 5 fuel fabrication plants in Germany, France, Spain, Sweden and the United Kingdom and the reprocessing facility in France all play a vital role in the security of supply in the EU.
- Although some progress has been made in licensing alternative fuel, the utilities operating exclusively VVER reactors are dependent on deliveries of fuel assemblies from one fabricator.
- The uranium inventories of EU utilities can fuel nuclear power reactors, on average, for 3 years.

4. Legal background and principles of security of supply

4.1. ESA's role under the EURATOM Treaty

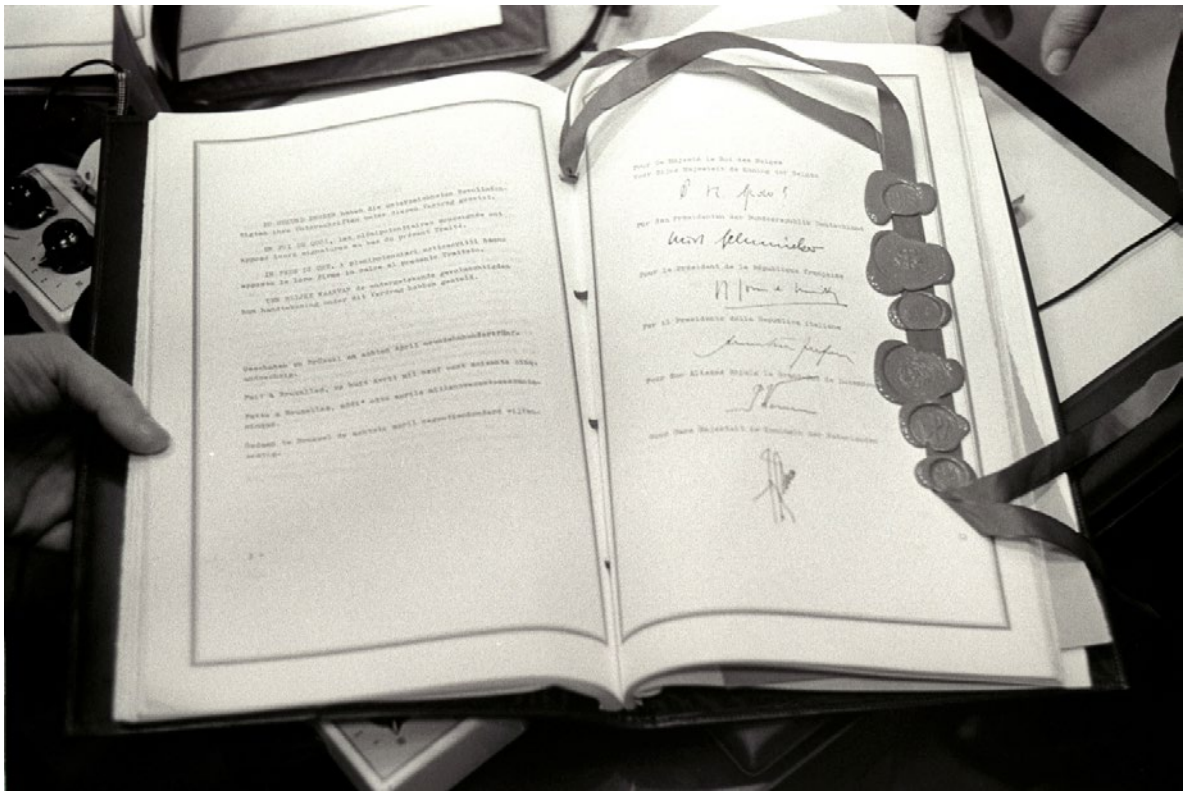
ESA's mandate under the Euratom Treaty is to ensure that all users in the European Union receive a regular and equitable supply of ores and nuclear fuels.

A common nuclear market was created by the Euratom Treaty, of which Article 52 established the Euratom Supply Agency (ESA) to ensure a regular and equitable supply of nuclear fuels to EU users in line with the objectives of Article 2(d). To perform this task, ESA applies a supply policy based on the principle of equal access of all users to ores and nuclear fuel.

In this context, ESA focuses on enhancing the security of supply of users located in the European Union and shares responsibility for the viability of the EU nuclear industry. In particular, it recommends that EU utilities operating nuclear power plants maintain stocks of nuclear materials and cover their needs by entering into long-term contracts with diversification of their sources of supply.

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

Article 52 of the Euratom Treaty requires ESA to conclude supply contracts for nuclear material (ores, source material and special fissile material) in accordance with the relevant provisions. Contracting parties are utilities, operators of research reactors in the EU or producers/intermediaries selling nuclear material (imports into or exports from the EU, as well as intra-EU transfers). When concluding supply contracts, ESA implements the EU supply policy for nuclear materials. ESA also has a right of option to purchase nuclear materials produced in the Member States.



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Merger Treaty of three Communities (ECSC, EEC, Euratom) signed 8 April 1965

On the basis of the Euratom Treaty, ESA also monitors transactions involving services in the nuclear fuel cycle (enrichment, conversion and fuel fabrication). Operators are required to submit notifications giving details of their commitments. ESA verifies and acknowledges these notifications.

Article 70 of the Euratom Treaty also gives the Commission the possibility to make recommendations to Member States on prospecting for mineral deposits and developing and exploiting them. Even financial support for uranium exploration within the territory of the Member States is seen as a possibility. To forestall any supply shortage, Article 72 allows ESA or the Commission to build up necessary stocks if and when the Council so decides.

4.2. ESA's market observatory role

As the nuclear fuel market is becoming increasingly complex, the ESA's remit was strengthened by a Council Decision of 12 February 2008 establishing ESA's Statutes, which entrusted the Agency with the creation of a nuclear market observatory in order to:

- provide expertise, information and advice on any subjects connected with the operation of the market in nuclear materials and services,
- monitor the market and identify trends that could affect security of the European Union's supply of nuclear materials and services.

ESA's observatory role has been extended to cover aspects of the supply of medical radioisotopes in the EU. This reflects the Council Conclusions 'Towards the Secure Supply of Radioisotopes for Medical Use in the EU' (2010 and 2012) prepared in response to the increasing fragility of the current production chain, which relies on an unsustainably low number of ageing research reactors. It also reflects the efforts to obtain the necessary supplies of nuclear material for enriched uranium targets used for radioisotope production.

The Advisory Committee, created to act as a link between ESA and both producers and users in the nuclear industry, also operates on the basis of the Statutes for the Euratom Supply Agency.

The Committee assists ESA in performing its tasks by giving opinions and providing analysis and information. Assistance also extends to the preparation of reports, surveys and analysis.

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Philippe COSTE conversion plant, Tricastin

The Committee members are appointed by the EU Member States on the basis of their relevant experience of and expertise on nuclear issues. The number of Committee members each Member State can appoint is laid down in the Statutes. The term of office is 3 years with the possibility of renewal. The Committee has to appoint a Chairperson and two Vice-Chairpersons from among its members. The Committee is convened when it is considered necessary and usually meets twice a year.

4.3. Mandate and objectives of the ESA Working Group on Prices and Security of Supply

The aim of the Working Group on Prices and Security of Supply is to support the Euratom Supply Agency in assessing possible shortcomings in the security of nuclear material supply and applying appropriate market monitoring tools. The Working Group helps the Agency to carry out its tasks by giving opinions and providing analyses and information. That assistance may also extend to the preparation of reports, surveys and analyses. The results of the activities undertaken by the group are reported to the Advisory Committee during its meetings.

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UF6 storage area at Georges BESSE 2 enrichment plant, Tricastin

The Working Group's mandate dates back to 2003, when during its meeting of 25 March 2003 the ESA Advisory Committee accepted the Agency's proposal to create a joint task force to assess 'the impact of all steps of the fuel cycle from the security of supply perspective'. This proposal was in line with the recommendations made by the Advisory Committee in its paper adopted on 14 February 2002 entitled 'the Future Role of the Euratom Supply Agency and its Advisory Committee'. In 2012, after some of the members of the Working Group were replaced due to expiry of their term of office in the Advisory Committee, the Working Group drew up its work plan for 2013 and 2014 and decided that one of its major tasks would be to update the security report issued in 2005. The updated report was published in 2015 and was well received by the industry. The same situation occurred in 2018, when some of the Working Group members were replaced and the newly composed Working Group decided to update the report of 2015.

The Working Group's members are either members of the Advisory Committee or experienced representatives of the nuclear industry, including service providers and utilities, delegated by them. The Working Group is expected to assist ESA with technical assessment in the following areas:

- methodology for calculating uranium price indices and ensuring the highest quality of the statistical tools for data processing,
- risk monitoring and analysis for the security of supply of nuclear fuel in the EU,
- long-term scenarios for EU nuclear fuel demand,
- long-term scenarios for nuclear fuel supply,
- evaluation of the EU situation from a worldwide perspective, including reports and analysis published by different bodies and agencies.

5. Risk analysis for security of supply in the nuclear fuel cycle

Methodology

All identified risk causes were assessed against the same criteria mentioned below. Members of the Working Group assessed their probability of occurrence according to a probability scale, the impact on supply according to a consequence scale and the duration of this impact according to the scale below. The top 10 risks were analysed in depth and appropriate risk mitigation measures were proposed.

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Remark: the update of the 2015 report included an update of the list of risks and an improvement of the ranking, namely a duration of the impact on supply was added to the scoring board; therefore assessment and conclusions cannot always be directly compared.

Table 1: Probability scale

Mark	Probability of occurrence
1	**Very unlikely** Has never happened or is very unusual
2	**Unlikely** Seen in the industry history, or seen as less likely for documented reasons
3	**Likely** Seen several times in the industry history, or seen as more likely for documented reasons
4	**Very likely** Seen several times during the past 10 years, or made almost inevitable for documented reasons

Table 2: Consequences scale

Mark	Consequence: Impact on supply
1	**Small impact** A limited number of market participants in a limited number of locations is likely to be affected
2	**Medium impact** A number of participants in different locations can be affected
3	**Strong impact** The risk has an impact on the whole industry

Table 3: Duration of impact on supply

Mark	Duration of Impact on supply
1	**Short term** Up to 1 year
2	**Mid-term** From 1 to 5 years
3	**Long term** From 5 to 10 years

5.1. Listing and classifying the risks

The risks were grouped into three categories: threats to supply and demand balance, commercial and technical causes and political and regulatory causes.

Tails management facility

A. Supply / demand balance

- Temporary suspension of production, or shortages in uranium mines
- Temporary suspension of production, or shortage of capacity of conversion
- Temporary suspension of production, or shortage of capacity of enrichment
- Temporary suspension of production, or shortage of capacity of fuel fabrication plant
- Lack of transport hubs open to nuclear shipments
- Concentration of nuclear transport companies
- Permanent reduction of production and withdrawal from uranium mining exploration
- Lack of investment in mines
- Lack of investments in conversion facilities
- Lack of investments in enrichment facilities
- Lack of investments in fuel fabrication facilities
- Uncertain availability of secondary supplies of uranium
- Uncertain availability of secondary supplies of conversion
- Uncertain availability of secondary supplies of enrichment
- Major industrial accidents in uranium mining industry
- Major industrial accidents in conversion industry
- Major industrial accidents in enrichment industry
- Major industrial accidents in fuel fabrication industry
- Increase of demand for uranium in the emerging markets leading to reduced supply in Europe
- Increase of demand for conversion services in the emerging markets leading to reduced supply in Europe
- Increase of demand for enrichment services in the emerging markets leading to reduced supply in Europe
- Increase of demand for fuel fabrication services in the emerging markets leading to reduced supply in Europe.

B. Commercial and technical

- Overdependence on any source of supply of uranium
- Overdependence on any source of supply of conversion services
- Overdependence on any source of supply of enrichment services
- Overdependence on any source of supply of fuel fabrication services
- Lessening of competition due to horizontal and vertical concentration of the business
- Permanent reduction in qualified fuel fabrication capacity
- Difficulties in the licensing of new fuel design
- Instability of the natural uranium market (U308, UF6) due to financial speculators.

C. Political / Regulatory

- Lack of harmonisation and multiple regulation in transport authorisation
- Delays and increased uncertainty of projects due to licensing/environmental regulations
- Supply disruption resulting from political instability
- Instability of taxation or regulatory or political interference (royalties)
- Reduced diversification of sources due to European trend to apply sustainability standards
- Un-harmonised non-proliferation constraints leading to reducing fungibility in the market, e.g. obligation codes
- Security of supply in light of the current political situation, e.g. restrictions on access to nuclear material and related services (temporary ban, bilateral restrictions).

5.2. Risk evaluation

All the risk causes listed above were evaluated independently by each Working Group member. Each individual cause received a rating according to the probability scale (see Table 1), the consequences scale (see Table 2) and the duration of impact on supply (see Table 3). An average score was produced by multiplying the two first ratings, and the result of the assessment of the duration of impact was included in a descriptive part of the risk evaluation. All the significant discrepancies were discussed and then generally reduced through consistent appraisal of the listed risks, according to the experiences recorded. As a result of the scoring exercise, a list ranking the top 10 risks was drawn up.

Table 4. Top 10 risks

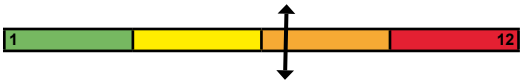
No.	Risk	Probability of occurrence	Impact on supply	Duration of impact	Final score
1	Lack of transport hubs open to nuclear shipments	3.20	2.30	2.00	7.36
2	Lack of investments in conversion facilities	3.10	2.20	2.60	6.82
3	Permanent reduction of production and withdrawal from uranium exploration	3.00	2.20	2.70	6.60
4	Lack of harmonisation and multiple regulation in transport authorisation	3.10	2.00	2.10	6.20
5	Temporary suspension of production, or shortage of capacity of conversion	3.00	2.00	1.80	6.00
6	Lack of investment in mines	3.00	1.90	2.70	5.70
7	Temporary suspension of production, or shortages in uranium mines	3.00	1.60	1.50	4.80
8	Security of supply in light of the current political situation, e.g. restrictions on access to nuclear material and related services	2.50	1.90	1.60	4.75
9	Supply disruption resulting from political instability	2.30	2.00	1.80	4.60
10	Overdependence on a single source of supply of fuel fabrication services	2.70	1.70	2.00	4.59

5.3. Summary of the top 10 risks

Risk 1 *Lack of transport hubs open to nuclear shipments*

A number of ports in Europe have taken the decision not to accept shipments of nuclear material any more. This was the case recently in Hamburg, where local political parties agreed on this in the coalition agreement and the port followed this agreement by a voluntary statement.

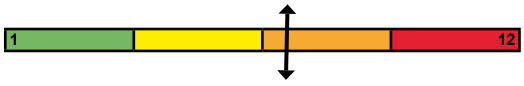
An increasing number of shipping companies are deciding to refuse nuclear fissile materials on their vessels (for instance Grimaldi, Hapag Lloyd, Stena Line).

Impact	Possible short or medium-term interruptions, consignment delays and even shipment denials, which in turn increases the costs of operations and may even jeopardise reactor operations. It is also a potential source of administrative burden.
Probability of occurrence	3.2 *(1= very unlikely to 4=very likely)*
Impact on supply	2.3 *(1= small impact to 3 = strong impact)*
Duration of impact	2.0 *(1= short term to 3 = long term)*
Total score	7.36 *(1= low risk to 12 =high risk)* 
Risk mitigation	Qualify new harbours. Use dedicated charter vessels instead of liner companies. Use alternative routes (roads instead of ships).

Risk 2 *Lack of investments in conversion facilities*

Installed UF_6 conversion capacity has significantly exceeded demand for years. This together with the extensive use of secondary supplies has resulted in quite depressed prices in the market. As a result, some conversion facilities stopped their production while those remaining in operation produced well below their nominal capacity. Additionally, producers have to comply with more demanding and stringent regulations for the environment, safety and security. In this way, taking any decision about investment in the conversion plants, either in operation or potential plants, is very difficult. Despite recent investment in the EU's conversion capacity and the recovery of market prices, the risk remains.

The lack of investments in conversion facilities may have consequences in the medium and long-term market, when some of the existing conversion facilities will be close to their obsolescence level. If the supply is reduced and not replaced, this may lead not only to an imbalance in supply and demand in terms of volumes, but also to less diverse supply sources. In addition, it can lead to different, generally more conservative policies for both buyers and suppliers.

Impacts	Temporary or permanent closure of one or several conversion facilities, leading to a reduction of capacity and inventories, more significant price increases, to the point where a shortage of natural UF_6 can occur.
Probability of occurrence	3.10 *(1= very unlikely to 4=very likely)*
Impact on supply	2.20 *(1= small impact to 3 = strong impact)*
Duration of impact	2.60 *(1= short term to 3 = long term)*
Total score	6.82 *(1= Low risk to 12 =High risk)* 
Risk mitigation	A diversified fuel supply (supplier, location, volumes and form) will reduce the risk of the utilities. Maintaining a strategic inventory of post-conversion material can help the utilities to bridge an unplanned non-availability of fuel. The volume, form and location should be monitored and updated according to the market situation.

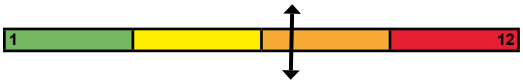
Risk 3 *Permanent reduction of production and withdrawal from uranium exploration*

A permanent reduction of production and withdrawal from uranium exploration are mainly the result of economic constraint.

When market conditions are unfavourable, the mining company may decide to reduce production, put a mine under care and maintenance or shut it down for good. Depending on the quantity of uranium removed from the market and the market share of the mining operator, the spot and long-term market price may increase as a result of this shortage of production.

The reduction of production can only be a temporary solution for a mining company, as a lower level of production reduces the competitiveness of the mine (fixed cost components account for a major part of the cost). If the impact on market prices is not as expected, a permanent closure of the mine will follow a first reduction of production.

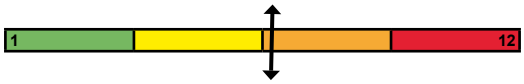
The lack of investment in new mines and withdrawal from uranium exploration may have consequences on the market in the medium and long-term, leading to an imbalanced market between production and demand of uranium.

Impacts	Shortage of nuclear material and a potential price increase if new developments are not in production on time to cover the demand. Higher exposure to country or supplier risk, given that the diversification would be more difficult to maintain.
Probability of occurrence	3.00 *(1= very unlikely to 4=very likely)*
Impact on supply	2.20 *(1= small impact to 3 = strong impact)*
Duration of impact	2.70 *(1= short term to 3 = long term)*
Total score	6.82 *(1= low risk to 12 =high risk)* 
Risk mitigation	A diversified fuel supply (supplier country, location, volumes and form) will reduce the risk of the utilities. Maintaining a strategic inventory of uranium can help the utilities to bridge an unplanned non-availability of fuel. The volume, form and location should be monitored and updated according to the market situation. Monitoring and surveillance of the risk and its evolution by industry and EU institutions can mitigate its impact.

Risk 4 *Lack of harmonisation and multiple regulation in transport authorisation*

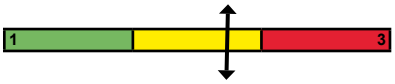
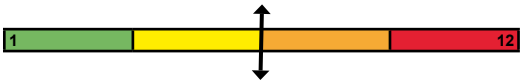
Lack of harmonisation and multiple regulation cause difficulties with nuclear transport, especially across borders.

Regulators have different approaches in each country, which can make freight scheduling a difficult and time-consuming issue. There are references in place like the 'Orange Book' of the UN ('Recommendations on the Transport of Dangerous Goods'), which deals with transport of nuclear material, and organisations facilitating nuclear transport like the European Association of Competent Authorities, which currently consists of 22 European authorities. Nevertheless, a complex system of national reporting and authorisation procedures for carriers of radioactive materials and the lack of a single pan-European arrangement for transport license approvals hampers operations.

Impacts	May lead to short or medium-term interruptions, consignment delays and even shipment denials. This in turn increases the costs of operations and may even jeopardise reactor operations. It is also a potential source of administrative burden.
Probability of occurrence	3.10 *(1= very unlikely to 4=very likely)*
Impact on supply	2.0 *(1= small impact to 3 = strong impact)*
Duration of impact	2.10 *(1= short term to 3 = long term)*
Total score	6.20 *(1= low risk to 12 =high risk)* 
Risk mitigation	Simplifying procedures and reducing administrative burdens would save time and resources. Different stakeholders should be made aware of the excellent safety record in the transport of radioactive materials. Developing a common EU project for licensing the transport companies for the transport of nuclear material on the territory of all EU countries may reduce the administrative burden and will lead to more cost-effective and less time-consuming shipments. The project initiated by the European Commission 'Modernisation & Optimisation of the European Nuclear Supply Chain' is recognised as an example of 'good practice'. Creating one pan-European arrangement for the approval of transport packages would help to improve conditions for services, especially with regard to cross-border transport. A diversified fuel supply (supplier country, location, volumes and form) to utilities further reduces the risk. A strategic inventory of material(s) held by utilities and suppliers can help bridge an unplanned non-availability of fuel.

Risk 5 *Temporary suspension of production, or shortages of capacity of conversion*

A temporary suspension of production of conversion services is usually a reaction to short or mid-term issues caused by e.g. non favourable market conditions, incidents in production, or changes in regulatory requirements.

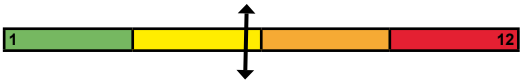
Impacts	Reduced production leads to reduction of overcapacities and inventories up to the point where availability of natural UF_6 becomes tight and prices start to rise. Eventually, the lack of UF_6 as feed for enrichment plants can lead to delay of fuel fabrication, extended outages and/or higher nuclear power plant operating costs. The probability of shortages of conversion supply is rather high as illustrated by the temporary suspension of US production since late 2017. The short-term availability of straight conversion and natural UF_6 has been impacted considerably and prices continue to rise quickly.
Probability of occurrence	3.00 *(1= very unlikely to 4=very likely)*
Impact on supply	2.00 *(1= small impact to 3 = strong impact)*
Duration of impact	1.80 *(1= short term to 3 = long term)* 
Total score	6.00 *(1= low risk to 12 =high risk)* 
Risk mitigation	On the production side, conversion and enrichment facilities can adapt their operating modes and have done so already, so that any usable UF_6 from their physical inventories is made available to supply the fuel chain. On their side, European utilities can rely on their UF_6 and EUP stockpiles, preferably at European enrichment facilities. Furthermore, long-term contracting of conversion services with producers protects utilities against scarcity of supply and helps producers to maintain and invest in their facilities.

Risk 6 *Lack of investment in new mines*

The current situation in the uranium market is leading to a lack of investment in new uranium mines. In many cases, the mining companies have to face a combination of factors that hampers the development of the project, such as more environmental requirements, insufficiency of funding and, most importantly, the uncertainty about future demand.

This non-investment situation may have consequences in the market in the medium and long term, when some of the existing mines start to deplete the reserves. If the supply is reduced and not replaced, because no new production enters the market, this may lead not only to a supply – demand imbalance in the future in terms of volumes, but also to a reduction in the supply sources with a centralisation of production. In addition, it can lead to a change in the utilities' purchasing or inventory strategies and to different, generally more conservative, policies for both buyers and suppliers.

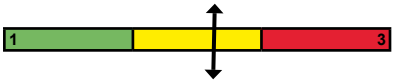
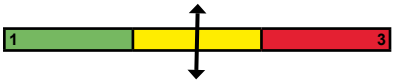
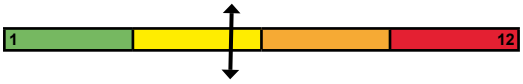
Excessive inventories may distort supply-demand forecasts and may lead to mistaken suppliers' investment decisions.

Impacts	Shortage of nuclear material and therefore a price increase if new developments are not in production on time to cover the demand. Higher exposure to country or supplier risk given that the diversification would be more difficult to maintain.
Probability of occurrence	3.00 *(1= very unlikely to 4=very likely)*
Impact on supply	1.90 *(1= small impact to 3 = strong impact)*
Duration of impact	2.70 *(1= short term to 3 = long term)*
Total score	5.70 *(1= low risk to 12 =high risk)* 
Risk mitigation	A diversified fuel supply (supplier country, location, volumes and form) will reduce the risk of the utilities. Maintaining a strategic inventory of uranium can help the utilities to bridge unplanned non-availability of fuel. The volume, form and location should be monitored and updated according to the market situation. Monitoring and surveillance of the risk and its evolution by industry and EU institutions can mitigate its impact.

Risk 7 *Temporary suspension of production or shortage in uranium mines*

The temporary suspension or shortage of uranium production could be the result of an unplanned interruption of production (e.g. an accident, flood or geopolitical problems) or a business decision based on adverse market conditions.

This situation can have consequences in the short term as it can lead to failures in planned deliveries. In addition, the feeling of scarcity can result in a sudden rise in prices, mainly spot ones.

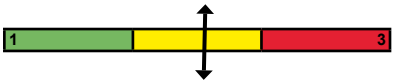
Impacts	Failure in deliveries of natural uranium. Sudden rise in prices, mainly spot. This can affect the price of supply contracts with market-related prices
Probability of occurrence	3.00 *(1= very unlikely to 4=very likely)*
Impact on supply	1.60 *(1= small impact to 3 = strong impact)* 
Duration of impact	1.50 *(1= short term to 3 = long term)* 
Total score	4.80 *(1= low risk to 12 =high risk)* 
Risk mitigation	Maintaining natural uranium inventories can replace material that cannot be delivered. Maximising the diversification in uranium supply (origin, volumes and form) will help the utilities to minimise the risk. ncluding flexibilities in supply contracts will help to cover unforeseen supply disruptions with material from other suppliers. Including protection clauses in supply contracts can protect against the supplier's failure to deliver.

Risk 8 *Security of supply in light of the current political situation, e.g. restrictions on access to nuclear material and related services*

In the 2015 report, this risk was entitled 'Restrictions on access to nuclear material and related services, e.g. temporary ban, bilateral restrictions, geopolitical factors'.

Like in many other industries, access to nuclear materials and services may be temporarily or indefinitely restricted for political reasons. For example, an exporting nation or one or more importing countries may decide to impose tariffs or quotas on quantities or values or completely suspend the sale, purchase, transport, storage or processing of nuclear materials in any form and of any origin. The restrictions may apply to all nations or be targeted at a particular nation or group of nations (be they suppliers, processors, consumers or a combination of some or all of these). Sanctions against other forms of trade (particularly financial), even by third parties, can indirectly trigger the risk.

Reasons for restricted access can be manifold and may be factual such as a preferential source to supply domestic needs in case of scarce resources, avoidance of excessive dependency on a single supply source, protection of the domestic nuclear industry, anti-dumping actions or sustainability issues. Restrictions, however, may also be driven by reasons that are completely outside the nuclear industry's sphere, such as trade conflicts or political disputes between nations or regions. They can be introduced at very short notice, or merely held as a threat (which itself will inhibit supply) and maintained as long as the imposing nation sees a benefit from doing so. Existing supply arrangements may or may not be allowed to endure (so called 'grand-fathering'). The restrictions may be acknowledged publicly or may be visible only through the failure (or excessive delays) to gain necessary licences/approvals or through the bureaucratic harassment of existing trade.

Impact	May lead to: • disruptions of supply (including inability to access own material); • loss at short-notice of established suppliers/routes to market, even from historically established (and reliable) trading partners, the loss being to both the imposing and recipient nation and also to third party intermediaries such as brokers/traders and processors; • rising fuel costs due to reduced competition, lack of available materials or services, reduced diversification; • disruption to wider transport and material flows (and thus book transfer liquidity/balances) to the detriment of third party utilities.
Probability of occurrence	2.50 *(1= very unlikely to 4=very likely)*
Impact on supply	1.90 *(1= small impact to 3 = strong impact)*
Duration of impact	1.60 *(1= short term to 3 = long term)* 
Total score	4.75 *(1= low risk to 12 =high risk)*
Risk mitigation	The maintaining by utilities and suppliers of a strategic inventory of material(s) can help bridge unplanned non-availability. Ensuring a diversified fuel supply (supplier country, location, volumes and form) to utilities further reduces the risk. The appropriateness of volume, form and location (of both the diversification and the inventory) should be regularly reviewed to take account of recent or potential political developments, both between the nations directly involved and in the context of third party influences (and should not place excessive reliance on past performance). Geopolitical monitoring by utilities, early warnings by EU institutions and concerted industry action may alleviate the impact.

Risk 9 *Supply disruption resulting from political instability*

In the 2015 report, this risk was addressed as part of the risk entitled 'Restrictions on access to nuclear material and related services, e.g. temporary ban, bilateral restrictions, geopolitical factors'.

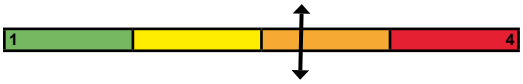
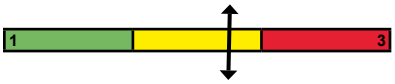
Like any trade, access to nuclear materials and services may be temporarily or indefinitely impeded by political instability that disrupts the established order. This can include: weakening, corrupting or suspending the rule of law and/or civil institutions; withdrawal (or external suspension) from international agreements/conventions (e.g. IAEA safeguards); piracy; terrorism; insurgency; regional secession; coups; and civil or international war.

The disruption may:

- physically prevent stable trade and access to materials;
- disrupt transport routes;
- pose unacceptable risks to staff;
- require ethically unacceptable associations or practices; or
- be commercially detrimental.

Disruption may be:

- sudden (such as after a coup) and total (in a given area);
- intermittent, making supply sources/routes unreliable; or
- particularly where it results from a degradation in the rule of law/civic institutions, increasingly over a prolonged period.

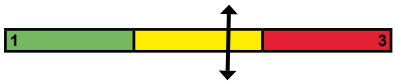
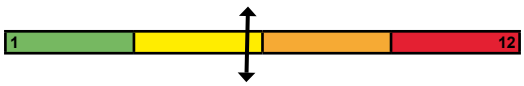
Impacts	May lead to: • disruption of supply (including inability to access owned material or facilities); • loss of established supply sources/routes; • rising fuel costs due to reduced competition, lack of available materials or services, reduced diversification; • reputational damage if parties continue to operate in the area; • reputational damage to the nuclear industry if international safeguards are perceived as compromised.
Probability of occurrence	2.30 *(1= very unlikely to 4=very likely)* 
Impact on supply	2.00 *(1= small impact to 3 = strong impact)*
Duration of impact	1.80 *(1= short term to 3 = long term)* 
Total score	4.60 *(1= low risk to 12 =high risk)*
Risk mitigation	The maintaining by utilities and suppliers of a strategic inventory of material(s) can help bridge disrupted availability. A diversified fuel supply (supplier country, location, volumes and form) to utilities further reduces the risk. The appropriateness of volume, form and location (of both the diversification and the inventory) should be regularly reviewed to take account of recent or potential political instability risks both between the directly involved nations and in the context of third party influences. Geopolitical monitoring by utilities, early warnings by EU institutions may alleviate the impact.

Risk 10 *Overdependence on a single source of supply of fuel fabrication services*

A limited number of companies in the world are involved in transforming uranium into fuel assemblies, but the EU industry has technological leadership on the whole fuel cycle chain, including fuel fabrication.

Most utilities have a diversified supply chain for nuclear materials and services. A utility (or nuclear power plant) which remains dependent upon a single source of supply for all nuclear materials and services is at greater risk of supply interruption.

Due to the technical specifications of fuel fabrication, it can be more difficult to establish alternative suppliers. Nevertheless, it is possible under certain conditions and enhances both short-term and long-term security of supply as well as levels of competition among suppliers, driving product performance and cost efficiency. Licensing an alternative fuel fabricator should be an overall goal for all nuclear power plant operators. Diversification also reduces risk exposure to a particular transport route or to systematic fuel failure.

Impact	May lead to the unavailability of fuel assemblies and eventually to reduced electricity generation due to a variety of factors, including design and licensing problems, political risk, transport logistics. May also lead to uncompetitive prices.
Probability of occurrence	2.70 *(1= very unlikely to 4=very likely)*
Impact on supply	1.70 *(1= small impact to 3 = strong impact)* 
Duration of impact	2.00 *(1= short term to 3 = long term)*
Total score	4.60 *(1= low risk to 12 =high risk)* 
Risk mitigation	Ensure the availability and licensing of an alternative producer of fuel assemblies. The maintaining by utilities of a strategic inventory of fuel assemblies can help bridge unplanned non-availability of fuel.

6. Recommendations and measures to mitigate the risks

Risks analysed in this report have been classified according to their connection with a particular fuel cycle stage or related problems, namely mining, conversion, access restrictions and disruption resulting from political instability, transport and overdependence on a single source of supply of fuel. The mitigation measures indicated as remedies against all of the analysed risks seem to be underpinned by a universal principle that all utilities should avoid disruptions in supply. The two major measures are:

- maintaining an **appropriate strategic inventory level**, and
- **diversifying the supply**.

Concerning a strategic inventory of material(s), the appropriateness of volume, form and location should be reviewed from time to time to take into account recent (political) developments. The inventories should be available in different chemical forms, and the volume and location should vary in time according to the perception of risks and anticipation of a changing global situation.

A diversified fuel supply with regard to supplier country, vendor of a product or service provider, location, transport route, volumes, fungibility and form should be maintained at an appropriate level at each stage of the nuclear fuel cycle. This will be the result of a specific risk analysis prepared by each utility.

A diversified fuel supply and an adequate inventory level — as described above — will enable flexible change from one supplier to another in the short term in order to overcome a disruption in supply.

In order to mitigate the risks that go with **uranium exploration, mines operation** and **lack of investing in mines**, the two major measures mentioned above are strongly recommended to all utilities. Moreover, EU institutions and industry should independently monitor the market and assess market trends to identify in advance possible risks.

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With regard to risks related to **conversion services**, besides universal mitigation measures, utilities are advised to contract long-term conversion services, which can help plant operators maintain and invest in their facilities.

Transport issues should be mitigated in several ways. Simplifying procedures and reducing administrative burdens, while maintaining the safe, secure and transparent transport of nuclear material, could result in saving time and resources. Developing a common EU project for licensing the transport companies for the transport of nuclear material on the territory of all EU countries could reduce the administrative burden and lead to more cost-effective and less time-consuming shipments. Creating one pan-European arrangement for the approval of transport packages would help to improve the conditions for services, especially in the case of cross-border transport. With ports closing their shipments for nuclear materials, other locations should be qualified, and dedicated charter vessels should be used for transportation instead of liner companies. Business stakeholders (ports, railways, authorities, etc.) should be made aware of the exemplary record of safety for the transport of radioactive materials in order to facilitate their licence approvals.

With regard to mitigation measures against risks associated with the security of supply due to the **political situation** and **instability**, the two major measures mentioned above should be applied by all utilities. Additionally, geopolitical monitoring by utilities, early warnings by EU institutions and concerted industry action could alleviate the impact.

Overdependence on a single source of supply of fuel fabrication services should be avoided by ensuring availability and licensing alternative suppliers of fuel assemblies. The maintaining by utilities of a strategic fuel assemblies inventory can help bridge an unplanned non-availability of fuel.

7. Conclusions

The Working Group on Prices and Security of Supply, which represents utilities, suppliers and intermediaries in the EU, has updated the Risk Analysis for Security of Supply in the Nuclear Fuel Cycle that was published in 2015.

This updated risk report will serve as a brief description of the main risks identified by the Working Group that could potentially threaten the security of fuel supply in the EU in the short or long-term. The report will also propose measures to prevent or limit the impact of each risk.

As a conclusion, fuel supply and inventories continue to be sufficient to ensure stable operations of all nuclear power plants in the EU. The situation of some of the different sectors of the global fuel market, however, has not improved since the publication of the 2015 risk report.

Unlike in 2015, the three biggest risks identified are a:

(1) lack of transport hubs open to nuclear shipments;

(2) lack of investments in conversion facilities;

(3) permanent reduction of production and withdrawal from uranium exploration.

Often unnoticed by end users, the **transport sector** is exposed to various challenges which can easily endanger the security of supply. Difficulty finding transport companies or ports to receive nuclear material shipments is becoming the main problem with transportation, making it increasingly expensive and more complex.

Conversion production has been curtailed as a consequence of low prices and surplus stocks. Investment decisions in new capacities, however, require stable prices on a sustainable price level, as construction and licensing often take a decade or more. If the supply is reduced and not replaced, this may lead not only to an imbalance in supply and demand in terms of volumes but also to a reduction in the diversification of the supply sources.

Reduction of uranium production and exploration will likely be more visible in the long term. Currently, the supply of concentrates is plentiful and prices are stable on a low level. Reduced U_3O_8 production is one measure by the mining industry to stabilise or push prices up by avoiding further excess production. Low prices also hamper the desire to invest in exploration, which is needed to discover and construct new mines to replace exhausted production and meet future demand growth.

In conclusion:

(a) Simplifying transport procedures and reducing administrative burdens would result in saving time and resources. Developing a project for licensing the companies transporting nuclear material that is common for the territory of all EU countries could reduce the administrative burden and lead to more cost-effective and less time-consuming shipments.

(b) To prevent the risk of shortages in nuclear fuel supply, appropriate levels of inventories should be maintained by EU utilities and producers. This could mitigate risks in the short term, but long-term investments in new facilities are needed. Since building new infrastructure is capital-intensive, it requires stable and favourable market conditions or government incentives to guarantee a return on investment.

In addition, EU industry should maintain technological leadership on the whole nuclear fuel supply chain. Resources of natural uranium located in different Member States can be considered a potential source of supply, at least from a long-term perspective.

It is recommended that ESA, through its established market observatory role and in regular dialogue with the Advisory Committee, review the identified risks and include references in its annual report so that all parties concerned can be made aware in order to take appropriate action to mitigate relevant risks.

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