

EURATOM AND IAEA SAFEGUARDS IN FRANCE: CURRENT SITUATION AND FUTURE CHALLENGES

Marianne CALVEZ

Euratom Technical Committee (CTE), under the Prime Minister's authority
Saclay, France

Audrey BARRIERE

Electricity of France (EDF)
Saint-Denis, France

Marika DEBRUYNE

Institute for Radioprotection and Nuclear Safety (IRSN)
Fontenay-aux-Roses, France

Priscillia LUGNIER

French National Agency for Radioactive Waste Management (ANDRA)
Châtenay-Malabry, France

Pierre MARCOT

Framatome
Romans-sur-Isère, France

Loïc ROUSSEL

Orano
Châtillon, France

Carin YOTA KETCHIEKMEN

French Alternative Energies and Atomic Energy Commission (CEA)
Fontenay-aux-Roses, France

Abstract

With the exception of mining, France has a complete nuclear fuel cycle, from ore concentrates to radioactive waste. Based on the legal framework of the Euratom Treaty, all civil nuclear materials, associated facilities or associated activities are safeguarded by Euratom wherever they are in France. International Atomic Energy Agency (IAEA) safeguards are applied in conjunction with the European Commission under the tripartite Voluntary Offer Agreement concluded between France, the Community and the IAEA, and its Additional Protocol. This paper recalls France's obligations to comply with the Euratom Treaty and international agreements on nuclear materials, and then presents the different stakeholders (authorities, main nuclear operators) and the installations subject to these controls (nearly 180 material balance areas). A summary of the safeguards, inspection and monitoring activities of each operator contributing to the different phases of the fuel life cycle is provided:

- Conversion, enrichment, reprocessing, Mox fuel fabrication and storage operated by Orano,
- Fuel targets fabrication operated by Framatome,
- Nuclear power plants operated by Electricity of France (EDF),
- Research and development conducted by the French Alternative Energies and Atomic Energy Commission (CEA), and
- Radioactive waste management facilities and disposals by the French National Agency for Radioactive Waste Management (ANDRA).

Finally, the authors outline the challenges facing their activities with the arrival of major new projects (new EPR2, SMR, etc.) of importance in the context of the national energy strategy for the decarbonisation of the economy and in the current context of tensions caused by the energy crisis due to the conflict in Ukraine. This paper presents the views of both the national authorities (Euratom Technical Committee, CTE and its technical support, Institute for Radioprotection and Nuclear Safety, IRSN) and the operators of French nuclear installations.

1. NUCLEAR SAFEGUARDS IN FRANCE

1.1. Legal basis for nuclear safeguards

The development of the civil nuclear energy was accompanied by the independent development of international legal provisions on, chronologically, nuclear Safeguards, nuclear Safety and nuclear Security. Later, with the maturity of these regimes came a reflexion on the welcomed synergies and interfaces between them, leading to what is called “the 3S Approach”. As a major Nuclear State with a large number of civilian nuclear facilities licensed from the 1950’s in almost every step of the nuclear fuel cycle, France has built 3 different regulations addressing these topics, based on different concepts, and a clear administrative organization with 3 corresponding different and independent regulatory bodies.

With regard to safeguards, the French international commitments are of key importance:

- With the IAEA and due to France's status as a Nuclear Weapon State: Voluntary Offer Agreement (VOA) between France, Euratom and the IAEA of July 27, 1978 (INFCIRC/290) in force since September 12, 1981 [1]; Additional Protocol (AP) of September 22, 1998 (INFCIRC/290/Add.1) in force since April 30, 2004 [2]; Safeguards Agreement for the Caribbean French territories of March 21, 2000 (INFCIRC/718) in force since October 26, 2007, together with the modifications on the Small Quantities Protocol of September 17, 2017, in force since February 25, 2019 [3];
- With Euratom: mainly the Euratom Treaty with the provisions of its chapter VII on safeguards and the regulation No 302-2005 of February 8, 2005 on the application of Euratom safeguards [4] ;
- With third countries: 9 bilateral Euratom nuclear cooperation agreements and 24 French cooperation agreements in the field of pacific use of nuclear energy.

The legal and regulatory French texts are mostly the consequence of the national enforcement of these commitments. Regarding the AP, the French provisions are for instance framed by the aw No 2016-113 of February 5, 2016 implementing the AP, the implementing decree No 2018-885 of October 12, 2018 and finally the order of March 13, 2020 setting out the content and terms of the required declarations and information.

Since the decree No 2021-713 of June 3, 2021, the Defence Code specifies the contribution of centralised nuclear material accounting to the monitoring of international commitments.

Furthermore, France has demonstrated its continued support for strengthening the Agency's safeguards system by adhering on a voluntary basis to other IAEA initiatives to strengthen safeguards, such as:

- INFCIRC/207/Add.1 (1984) [5] on imports and exports of nuclear materials;
- INFCIRC/415 (1992) [6] on production and imports and exports of mining concentrates;
- INFCIRC/549 (1998) [7], a transparency exercise to declare annually the stocks of civilian plutonium held in France (as well as those of highly enriched uranium).

1.2. National authority

According to the decree No 2011-607 of May 30, 2011, the Euratom Technical Committee (CTE) is the French Safeguards Authority. It is a Prime Minister’s entity in charge of ensuring the implementation of the IAEA VOA and AP (declarations, inspections) and of the chapter VII of the Euratom Treaty, as well as of monitoring the implementation of France's international commitments in the nuclear field, in cooperation with other ministries (Energy, Foreign Affairs, etc.). It follows up the implementation of international safeguards in the French facilities and for the civil nuclear material. CTE has a direct contact with the IAEA and the European Commission, as well as with any French nuclear operator to help him understand and implement the international requirements.

1.3. Technical support of the national authority

To help in its missions on safeguards, CTE relies on the technical support of the Nuclear Bureau of the IRSN (Institute for Radioprotection and Nuclear Safety). The TSO provides support to the French authority for the application of European law arising from the Euratom Treaty and France's commitments in the field of nuclear non-proliferation.

Its main activities consist of advising the CTE and assisting operators on technical and regulatory issues relating to the monitoring of nuclear installations. In particular, in the context of the application of INFCIRC/290 and the regulation No 302/2005, the Nuclear Bureau is more specifically responsible, for the civil nuclear sector, for managing France's declarations, preparing and accompanying many international inspections per year as a representative of the French authorities, and evaluating documentation.

1.4. Safeguards inspections

Euratom and the IAEA are both implementing inspections for safeguards purposes in France. In 2022, they performed all together 313 inspections, with an effort of 1 469 person.day in the French facilities.

The international safeguards inspections being numerous and very comprehensive, France chose not to develop a proper set of additional national safeguards requirements and not to have national safeguards inspections. Instead of inspectors, France has an interface to facilitate relations between international inspectors and operators, with national representatives sometimes accompanying the international inspections. CTE and its technical support IRSN are organized to accompany IAEA inspections and complementary accesses when conducted in France, as well as some Euratom inspections in France, with an average of 50 accompanied inspections per year.

It is worth noting that in addition, the implementation of the national regulation relating to the protection and control of nuclear materials (including monitoring and accountancy) is based on inspections performed by the Ministry of Energy Transition.

1.5. Types of nuclear facilities and locations

France is an important nuclear country, as proves the current French nuclear panorama (see Figure 1):

- 176 Material Balance Areas (MBA) in 2022 on 43 sites all over the territory, including overseas;
- All the steps of the nuclear fuel cycle except mining;
- 4 main operators known worldwide: Orano (conversion, enrichment and reprocessing); Framatome (fuel fabrication); EDF (electricity production); CEA (research);
- 56 Nuclear Power Plants (NPPs) in operation;
- A public company, Andra, for the long-term radioactive waste management.

France also operates about 400 nuclear and non-nuclear location outside facilities, which clearly reflects the wide use of nuclear material in non-nuclear activities (medical applications, universities, etc.).

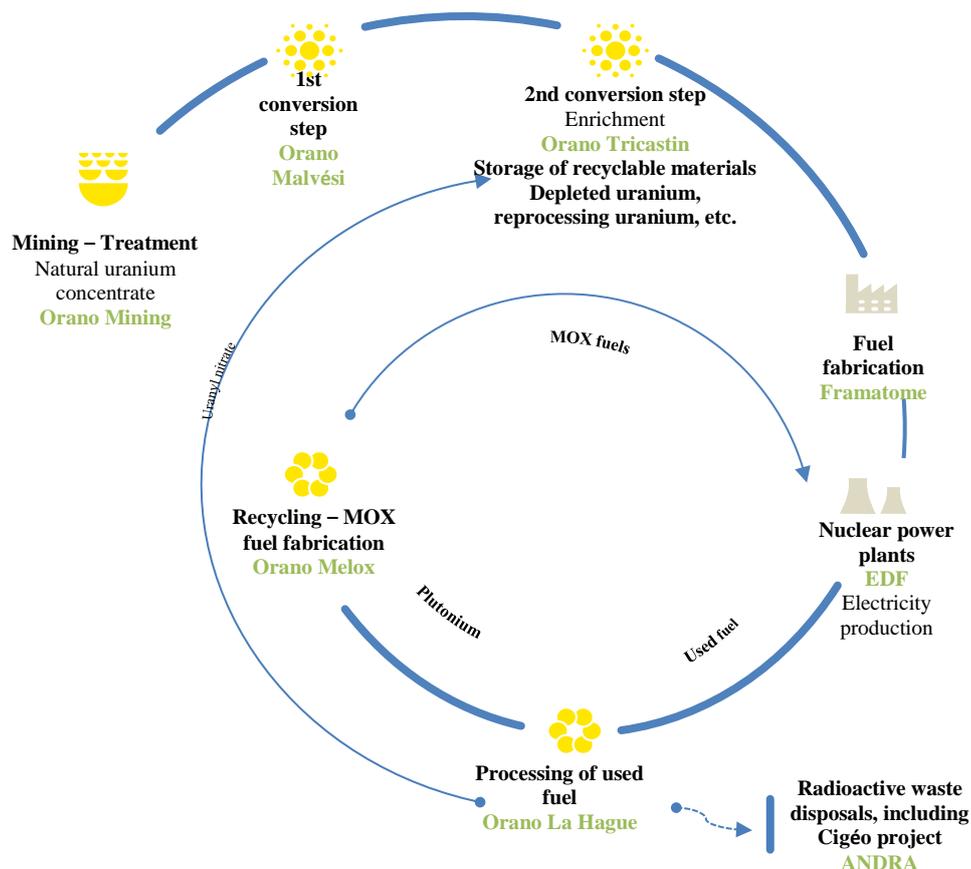


Figure 1 – The nuclear fuel cycle in France © Orano

2. SAFEGUARDS IMPLEMENTATION IN FRANCE

2.1. Euratom safeguards

Euratom has verified all French facilities holding nuclear materials for civilian use since 1960.

In this context, French operators must:

- Keep local accountancy records and operating records and reports;
- Transmit their declarations to the European Commission in Luxembourg, through the French authorities (the CTE and its technical support, the IRSN): the Basic Technical Characteristics (BTC), the program of activities; as well as accounting reports (Inventory Change Report (ICR), Material Balance Report (MBR) and the Physical Inventory Listing (PIL));
- Send prior import/export notifications.

On-site verifications are subject to various types of inspections: BTC verification, routine inspection, physical inventory verification, short notice and unannounced inspection.

41	French nuclear sites regularly monitored by the European Commission
176	Material Balance Areas controlled by the European Commission
297	Euratom inspections in France
13	Joint Euratom and IAEA inspections in France
1 391	Persons.days of Euratom inspections effort
51	Escort of Euratom inspections by the French authorities
312 189	Accountancy lines for nuclear material inventory changes submitted to the European Commission
234	Initial programmes of activities planned for the year in French facilities, sent to the European Commission
900	Transfers of nuclear materials announced to the European Commission through 1 533 notifications (including intra-EU transfers)

Figure 2 – Key figures for Euratom verification in France in 2022.

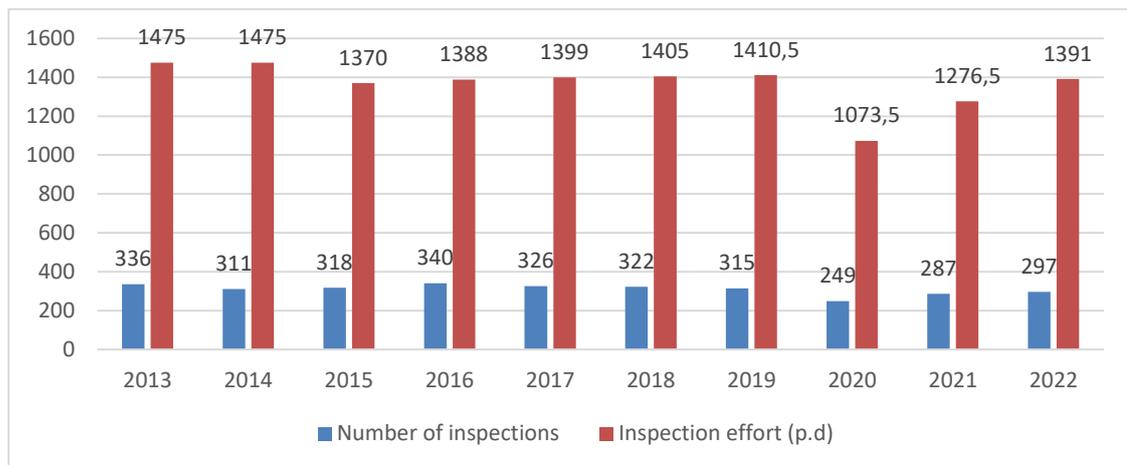


Figure 3 – Evolution of the number and effort of Euratom inspections in France.

Between 2013 and 2019, the figures showed a fairly small variation in the number of inspections as well as in the inspection effort of Euratom in France. The year 2020 was particular due the Covid-19 health crisis, with a 20% drop in the number of inspections as well as in the inspection effort, while the year 2021 is still marked by the effects of the health crisis and the difficulties of the European Commission regarding its number of inspectors and results in a significant decrease in routine inspections. In 2022, the number of inspections increased slightly compared to 2021.

In 2022, there was an average of five inspectors present at French nuclear facilities each working day. France is therefore the most inspected country in the European Union.

Figure 4 shows the distribution of MBAs by operator in 2022. Moreover, the two MBAs relating to external accounts and the Caribbean area under the Treaty of Tlatelolco (INFCIRC/718) are not included in this total, as they are specific 'catch-all' MBAs not representative of a facility.

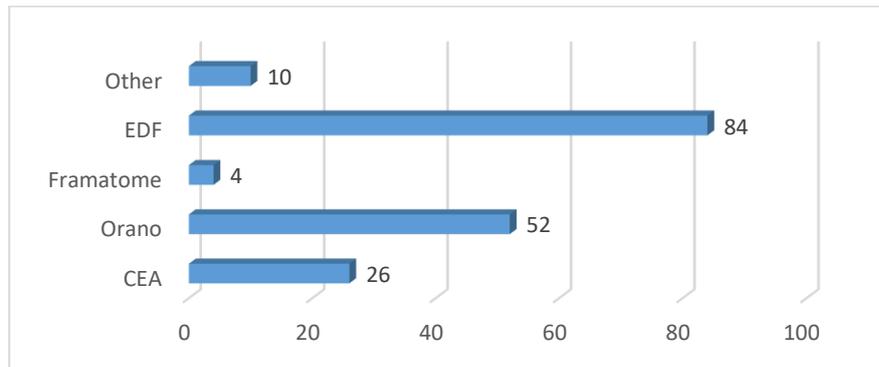
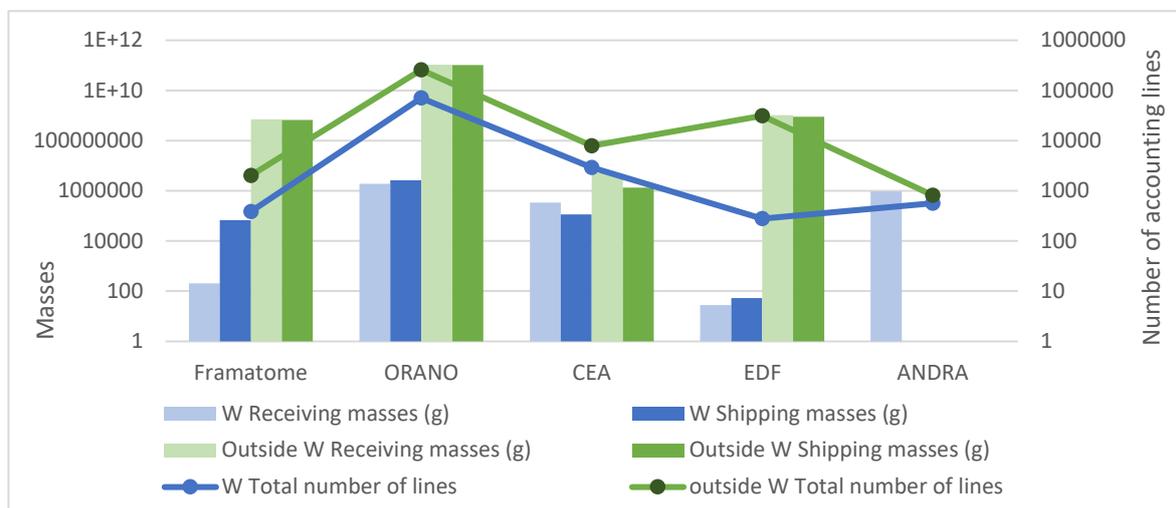


Figure 4 – Distribution of MBAs by French operators in 2022.

In terms of accounting declarations, it should be noted that operators make a considerable effort to declare operations involving non-noble materials, such as waste. By way of illustration, the number of declaration lines for the main operators has been extracted from the national accountancy for the year 2022 and grouped according to whether they concern movements under W code (waste) or not (see Figure 5). Thus, it shows that accounting declarations relating to waste represent a third of non-waste movements, for much smaller masses (less than 0,003% of the total, whether in receipts or shipments). These conclusions support the French authorities' requests to adapt the Euratom safeguards control in place for these non-noble and low-value materials to the issues at stake.

Figure 5 – Declarations lines and masses for W code and outside code W movements in 2022



2.2. IAEA safeguards

In 2022, 17 installations were eligible for IAEA routine inspections, i.e. 38 MBAs. Three installations or parts of installations are selected by the IAEA (the reprocessing plant of La Hague, the centrifuge enrichment plant of Georges Besse II, and the MOX fuel fabrication plant of Melox) and are effectively inspected.

16 inspections were carried out by the IAEA in France in 2022, representing 78 person-days of inspections.

In addition, France prepares many declarations and submits them to the IAEA for its facilities subject to safeguards agreements at all stages of the nuclear fuel cycle.

3	French nuclear facilities selected for inspection by the IAEA and monitored
38	Material balance areas eligible for IAEA inspection
16	IAEA inspections in France
78	Persons.days of IAEA inspections
3	Accompaniment of IAEA inspections by the French authorities
91 705	Accounting lines for nuclear material inventory changes transmitted to the IAEA via the Commission
42	Initial programmes of activities planned for the year 2022 in French installations, sent to the IAEA via the Commission
151	Transfers of nuclear material reported to the IAEA through 305 notifications

Figure 6 – Key figures for IAEA verification in France in 2022.

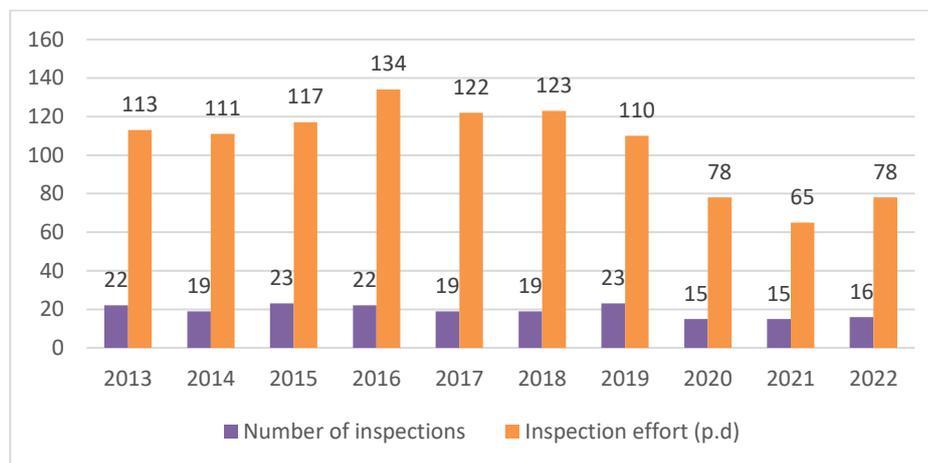


Figure 7 – Evolution of the number and effort of IAEA inspections in France.

The new control approach based on the continuous collection and analysis of operational data at the Georges Besse II plant, fully implemented since November 2020, has allowed the IAEA inspection effort to be reduced, while maintaining the same level of confidence for the inspectorate.

3. SAFEGUARDS INSPECTION AND SURVEILLANCE ACTIVITIES OF NUCLEAR OPERATORS

3.1. Conversion, enrichment, reprocessing, fabrication of MOX fuel by Orano

Orano is a leading international group and a key player in the nuclear energy sector. With 17,000 employees worldwide, the group is committed to meeting the world's energy challenges on a daily basis, by helping deliver plentiful, safe, low-carbon and competitive electricity. With over 50 years of experience, Orano offers a wide range of services to its customers in the nuclear industry and beyond, from mining to transportation, decommissioning and waste management to engineering services worldwide.

Orano sites in France, representing 52 MBAs, are under Euratom Safeguards and partially controlled by the IAEA.

As in previous years, the facilities operated by Orano are by far the most inspected in France. This is due to the status of the nuclear material present in many of its facilities, which is in bulk, more difficult to track and sometimes more accessible, and therefore more exposed to potential diversion.

Main verification tools implemented by the inspectors are identification, counting, weighing, sampling, video surveillance, seals and detectors.

In La Hague Fuel Recycling plant, since the beginning of the 2000's, the inspectors are backed with an On-Site-Laboratory, which is operated directly by Euratom, allowing an efficient control on a relevant timeliness basis. In order to allow Euratom to carry out, from Luxembourg, preparations and verifications in the framework of inspections on the Orano site in La Hague, an existing local network was set up and equipped with an encrypted telecommunication system between the inspectors' offices on the Orano site in La Hague and a dedicated room in the Euratom premises in Luxembourg. Thus, the Remote Data Transmission (RDT), which is the result of several years of (cyber)security discussions between the European Commission, the operator and the French authorities, is fully operational since the beginning of 2022.

The enrichment plant Georges Besse II at Tricastin site presents also safeguards particularities:

- Since 2008, the operator, the State authorities, Euratom and the IAEA cooperated, through the French and the European Commission support programmes, on the development of a new approach based on the recording and analysis of operational data. Dedicated software tools were created by the Joint Research Center (JRC) for IAEA and Euratom inspectorates, to enable continuous data collection from the cylinder weighing and mass spectrometry systems. The data is immediately secured under the inspectorates' custody and can be retrieved for analysis;
- It enables the verification of declared uranium content and isotopic composition in each and every tails and product cylinder produced;
- In addition, Limited Frequency Unannounced Access (LFUA) are used by inspectorate to provide confidence that the data collected when inspectors are not present remained valid, genuine, and representative of the plant operation. In 2022, 6 LFUAs were carried on the enrichment plant.

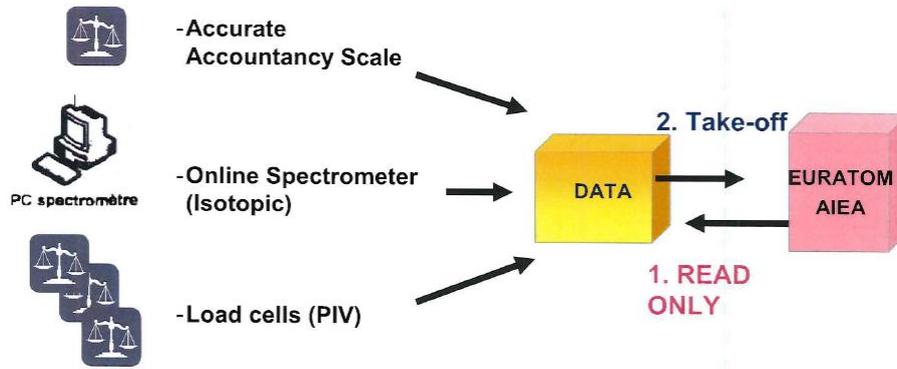


Figure 8 – Georges Besse II Data acquisition for Safeguards.

3.2. Fuel fabrication by Framatome

For over 60 years, Framatome's teams have been involved in developing safe, competitive, clean, low-carbon nuclear energy worldwide through 5 activities:

- Engineering & Design Authority: Development, design and licensing of Nuclear Steam Supply System and associated services, including worldwide Technical Centers;
- Projects and Components Manufacturing: Design and manufacturing of heavy and mobile components for nuclear islands. Management and execution of nuclear reactor new build projects, as well as component replacement projects;
- Instrumentation & Control (I&C): Design and fabrication of safety I&C and automation systems for nuclear power plants;
- Fuel: Development, design, licensing and fabrication of fuel assemblies and core components for power reactors (PWR, VVER, BWR) and research reactors, and development of zirconium products;
- Products, maintenance and engineering services for nuclear fleets and reactors under construction.

With 15,000 employees over 60 sites in 20 countries, Framatome is the original equipment manufacturer of 92 nuclear power plants. 230,000 Framatome fuel assemblies are loaded in more than 125 reactors in operation around the world.

In France, 4 MBAs are currently under Euratom Safeguards, all located in Romans-sur-Isère where fuel assemblies are produced for power reactors and research reactors.

On main MBAs, inventory verification performed by at least five inspectors lasts one week.

Two types of inspections are currently driven by EURATOM inspectors on Framatome's site:

- Interim routine inspection (ERR): each month, generally performed by two inspectors;
- Short Notice Random Inspections (SNRI): these inspections are notified 48 hours before the arrival of the Euratom inspectors on site and there is about six per year, generally performed by two inspectors.

The main verification devices used by Euratom during their control are as shown in Figure 9. Previously, two neutron detectors, two cameras and video recorder (signal retransmitted to the inspector office onsite) for fuel assemblies control were also used in combination with electronic seals, but were abandoned when the Euratom control approach changed.





Figure 9 – Main verification devices used by Euratom in Framatome facilities. © Framatome

3.3. Nuclear power plants operated by Electricité de France (EDF)

EDF is a world leader in low-carbon electricity generation: 91 % of its electricity production worldwide does not emit any CO₂. EDF produces safe, affordable and carbon-free electricity in power plants which it designs and operates.

In France, the electricity produced by EDF is more than 97% CO₂ free, thanks to nuclear power and renewable energies and 87% is from nuclear origin.

In 2021, EDF's specific carbon emissions in France delivered the figure of 16 g/kWh - including direct CO₂ emissions related to production, excluding life-cycle assessment of production means and fuel produced - (vs 13 g/kWh in 2020), 14 times less than the European average for the sector.

84 EDF MBAs are currently under Euratom safeguards control: 56 reactors in operation (commissioned progressively since 1975) located on 18 sites, 1 in construction and 3 in decommissioning phase, 3 storage installations, 2 waste treatment or waste storage installations and 19 other installations (gammagraphy devices storage facilities on NPP's site).

An inventory verification lasts generally one day by one inspector. However, for one storage installation, the verification can take up to one week.

The main verification devices used by Euratom during their control are as follows (see Figure 10):

- ICVD for fuel stored in pools;
- HM-5 IdentiFINDER for fuel stored in dry storage;
- Pond seals, camera and video recorder (signal retransmitted to the inspector office onsite) for one storage installation.

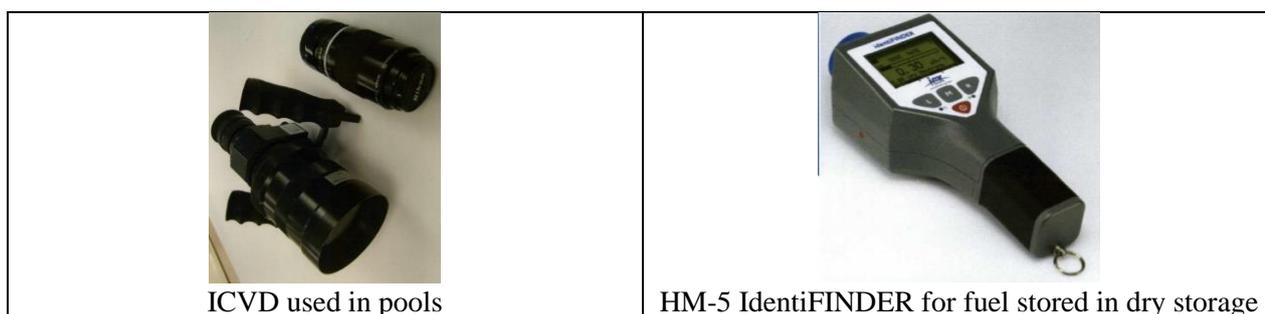


Figure 10 – Main verification devices used by Euratom in EDF NPPs. © EDF

3.4. Research and development conducted by the French Alternative Energies and Atomic Energy Commission (CEA)

The French Alternative Energies and Atomic Energy Commission (CEA), a State-owned public organisation, is a key player in research, development and innovation in four main areas:

- Defence and security;
- Low carbon energies (nuclear and renewable energies);
- Technological research for industry;
- Fundamental research in the physical sciences and life sciences.

Drawing on its widely acknowledged expertise, the CEA actively participates in collaborative projects with a large number of academic and industrial partners worldwide. With more than 21,000 employees in nine centers in France, CEA works in partnership with many other research bodies, local authorities and universities.

To meet both the current and future stakes of the energy transition which is indispensable to fight climate change, the CEA has been leading research on low-carbon power systems combining nuclear (i.e. current nuclear reactors, nuclear fuel cycle, SMRs and fourth-generation reactors) and renewable energies (i.e. solar power, hydrogen). This research covers low-carbon power production methods, the systems used for energy storage, control, conversion and resource management within a circular economy strategy. This wealth of expertise serves the interests of the French public authorities and industry players.

The CEA civil sites consist of 26 MBAs under Euratom safeguards: 1 research reactor in construction, 1 in operation and 5 in decommissioning phase, 4 interim storages, 16 waste treatment or waste interim storage facilities, and 24 other research facilities in operation. None of these facilities were chosen by the IAEA for regular inspections.

Tree types of Euratom inspections are currently driven on CEA's sites:

- ERI: physical inventory verification, which are the most common;
- ERR: routine inspection to a lesser extent;
- EAD: Basic Technical Characteristics verification inspection.

3.5. The radioactive waste management and disposal facilities of the National Agency for Radioactive Waste Management (ANDRA)

Andra, the French National Agency for Radioactive Waste Management, is a State-owned undertaking of industrial and commercial nature, and is in charge of long-term radioactive waste management on the French territory. Since 1991, Andra is supervised by the French ministers of Energy, Research and Environment. Andra is independent from waste producers.

Andra's national missions are:

- To study and develop solutions for sustainable management of those types of radioactive waste that do not yet have a final disposal method: high-level waste, intermediate-level long-lived waste and low-level long-lived waste;
- To construct, operate and monitor the French radioactive waste disposal facilities;
- To update the National Inventory of Radioactive Waste and Materials in France, inform the public and encourage the dialogue with stakeholders;
- To develop scientific cooperation on national, European and international levels and to promote its safety, scientific and technical culture as broadly as possible.

In the Aube district, Andra operates two disposal facilities, one dedicated to very low level waste, namely the Cires, and the second for low level and intermediate level – short lived waste, namely the CSA. All the waste containing radioactive material are under Euratom safeguards since their reception at Andra's facilities. Euratom inspections are regularly driven with specific attention on their physical inventories and accountability.

In 2023, Andra applies for an extension of 250,000 to 300,000 m³ of the current licensed disposal capacity of the Cires.

Cigéo is the French deep geological repository project for high level waste led by Andra. The public utility of Cigéo and the recognition of its national importance for France was declared in July 2022. By the beginning of 2023, Andra submitted the license application for its construction. The preliminary declaration for the Cigéo project was sent to the European Commission at the end of 2021. It is a document prefiguring the Basic Technical Characteristics, in order to start discussions on the safeguards that will be carried out there, in a logic of safeguards by design (SBD).



Figure 11 – Andra's disposal facilities in the Aube (Cires on left, CSA on right). © Andra

4. FUTUR CHALLENGES

France has exciting perspectives in terms of nuclear energy and in particular with the construction of new nuclear power plants since the construction of 6 new EPR-2 was announced. Within the framework of the "France 2030" investment plan, 500 M€ will be devoted to "innovative nuclear reactors" and the same amount to nuclear technologies. The French Government also supports EDF's Nuward SMR project, with the goal of the first concrete of the first one in 2030.

At the same time, it will also have challenges to overcome with the arrival of those major new projects (new EPR2, SMR, etc.) and the dismantling of the existing nuclear facilities.

Regarding Orano, a project to extend the Georges Besse II enrichment plant is in progress, in order to meet the challenges of uranium production for civilian use. Orano's nuclear medicine division is also planning to build a plant in France to produce lead-212, a rare isotope used in cancer treatments.

With the acceleration of new nuclear projects, EDF encounters new safeguards challenges with the deployment of SBD discussions with Euratom for its new projects: one storage installation, several EPR-2 and the Nuward SMR. This approach is particularly important early in the design phase for installations that aren't similar to existing ones. For Nuward SMR intended for export, SBD discussions are also held with the IAEA as part of the French Support Programme for IAEA Safeguards (FRESPAS).

The Framatome site is undergoing many changes, such as the New Uranium Zone dedicated to the production of uranium oxide powder for the manufacture of fuel assemblies in CERCA (for research reactors) or the new storage of enriched reprocessed uranium. Efforts are being made to integrate SBD before modifying facilities or in new projects.

CEA will also face major challenges with the upcoming dismantling of its research facilities and with the future commissioning of its Jules Horowitz research reactor (JHR).

ANDRA is actively preparing Cigéo, the French project for a deep repository for radioactive waste and is already integrating SBD.

5. CONCLUSION

With a large nuclear industry full of projects, France is committed to remaining exemplary and on top of the safeguards performed by the IAEA and Euratom. It put in place a robust organisation from the local level with each nuclear operator up to the national level, with the CTE and its technical support IRSN, to facilitate relations with the international authorities prepare safeguards declarations and provide support to operators. Thanks to this organisation, and to a constructive and quality dialogue with all the stakeholders including AIEA and Euratom inspectors, France is allowed to ensure the best possible consideration of international safeguards provisions. On a voluntary basis and because it is a win-win approach, France takes SBD into account in its numerous nuclear projects and has already started early discussions with the IAEA and Euratom for mutual benefits.

6. REFERENCES

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